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# Particulate Emission Factors Applicable to the Iron and Steel Industry

Midwest Research Inst.
Kansas City, MO

Prepared for

Environmental Protection Agency
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An intensified effort has occurred in the last 3 years to update the iron and steel industry particulate emission factors presented in AP-42 and to add, for the first time, fugitive source emission factors.

It is the objective of this report to present the results of this data gathering and analysis effort. The report is divided into three major areas. First, background information will be presented related to the processes in the iron and steel industry along with a process flow chart. Second, all of the particulate source test data will be presented and summarized in chart form. Third, the methodology for selecting single source specific emission factors and the resulting particulate emission factors will be presented.

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Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
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September 1979

## PREFACE

This report was prepared for the Environmental Protection Agency (Mr. Charles Masser, Project Officer) under EPA Contract No. 68-02-2814. The work was performed in the Environmental and Materials Sciences Division of Midwest Research Institute, under the supervision of Dr. Chatten Cowherd, Head, Air Quality Assessment Section. Mr. Thomas Cuscino, Jr., Project Leader, is the author of this report. He was assisted in data compilation by Mr. Mark Golembiewski and Dr. Ralph Keller. Mr. Charles Masser wrote the Introduction of this report.

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# SECTION 1.0

# INTRODUCTION

An intensified effort has occurred in the last 3 years to update the iron and steel industry particulate emission factors presented in AP-42 and to add, for the first time, fugitive source emission factors. The emission factors in AP-42 for the iron and steel industry are dated April 1973.[1]

The intensified effort began in August 1975 when Gary McCutchen of the Environmental Protection Agency's (EPA's) Emission Standards and Engineering Division (ESED), Office of Air Quality Planning and Standards (OAQPS) compiled a table of particulate point and fugitive emission factors for eight generic categories of sources. By March 1976, a task force consisting of the American Iron and Steel Institute (AISI) Fugitive Emission Committee and specific EPA personnel had been formed at the request of the director of OAQPS.

In July 1976, AISI presented a compilation of particulate source test data performed at AISI member plants.[2] This compilation and its support documentation provided significant new test data and became the focal point of discussions for the following 2 years. From late July until November 1976, Peter Westlin, Test Support Section, OAQPS, reviewed the support data and corresponded with Bill Benzer of AISI to acquire additional information necessary to evaluate the AISI compilation of test results. By mid-November, Mr. Westlin had selected a major portion of the tests presented in the AISI compilation as acceptable. The task force discussions since November 1976 centered mainly on the development of a methodology which would result in single emission factor values to represent each process stack, process fugitive, and open dust source.

It is the objective of this report to present the results of this data gathering and analysis effort. The report is divided into three major areas. First, background information will be presented related to the processes in the iron and steel industry along with a process flow chart. Second, all of the particulate source test data will be presented and summarized in chart form. Third, the methodology for selecting single source specific emission factors and the resulting particulate emission factors will be presented.

All of the particulate emission source test data that were in the possession of the EPA/AISI task force on June 1, 1979, have been included in the evaluation and emission factor development. If you, as the reader, feel you are in possession of documented source test data that would further enhance the understanding of emissions from processes within the iron and steel industry, please send a copy to the present EPA task coordinator:

Charles C. Masser (MD-14)
Environmental Protection Agency, OAQPS
Monitoring and Data Analysis Division
Research Triangle Park, North Carolina 27711

As with all average or "typical" emission factors, they are obtained from a wide range of data of varying degrees of accuracy. The reader must be cautioned not to use these emission factors indiscriminately. That is, the factors generally may not yield precise emission estimates for an individual installation. Only on-site source tests can provide data sufficiently accurate and precise to determine actual emissions for that source. Emission factors are most appropriate when used in diffusion models for the estimation of the impact of proposed new sources upon the ambient air quality and for community or nationwide air pollution emission estimates.

This report represents the combined efforts of EPA and steel industry experts to establish reasonable particulate emission factors with ranges for all known stack and fugitive sources within an integrated steel mill. The EPA task coordinator wants to thank the AISI Fugitive Emission Committee, the EPA ESED, the Industrial Environmental Research Laboratory (IERL), Research Triangle Park, the Enforcement Division of the EPA Regional Offices, and the EPA Division of Stationary Source Enforcement in Washington, D.C., for the data and review comments which resulted in this report.

# SECTION 2.0

# BACKGROUND

Particulate emission sources in the iron and steel industry can be generically classified as (a) process stack emission sources, (b) process fugitive emission sources, and (c) open dust sources. Process stack emissions are any emissions exhausted to the atmosphere through a stack duct, or flue. Process fugitive emissions and open dust sources are both defined as any emissions not entering the atmosphere from a duct, stack, or flue. Open dust sources traditionally have included (a) vehicular traffic on paved and unpaved roads, (b) raw material handling outside of buildings, and (c) wind erosion from storage piles and exposed terrain, while all other nonducted sources have been classified as process fugitive emissions.

Figure 1 portrays a process flow diagram for a representative integrated iron and steel plant. Industry-wide material flows are presented in Figure 2. The Appendix presents typical material quantity conversion factors useful in calculating material flows.

Table 1 shows the main sources of particulate emissions in the integrated iron and steel industry. Not all sources are listed, but those of most common interest are shown. Such sources as dry quenching, hot metal desulfurization, and argon-oxygen decarburization will not be considered, since little or no data are currently available.

## 2.1 BY-PRODUCT COKE OVEN PROCESS

Coking is the process of heating coal in an atmosphere of low oxygen content, i.e., destructive distillation. During this process, organic compounds in the coal break down to yield gases and a residue of relatively nonvolatile nature.

The integrated iron and steel industry produces coke using the by-product process. This process will not be found at plants which produce steel only via the electric arc furnace process. Plants producing steel via the basic oxygen furnace or open hearth furnace process will normally have a coke plant but this is not always the case since some plants have their coke brought in by rail or barge.

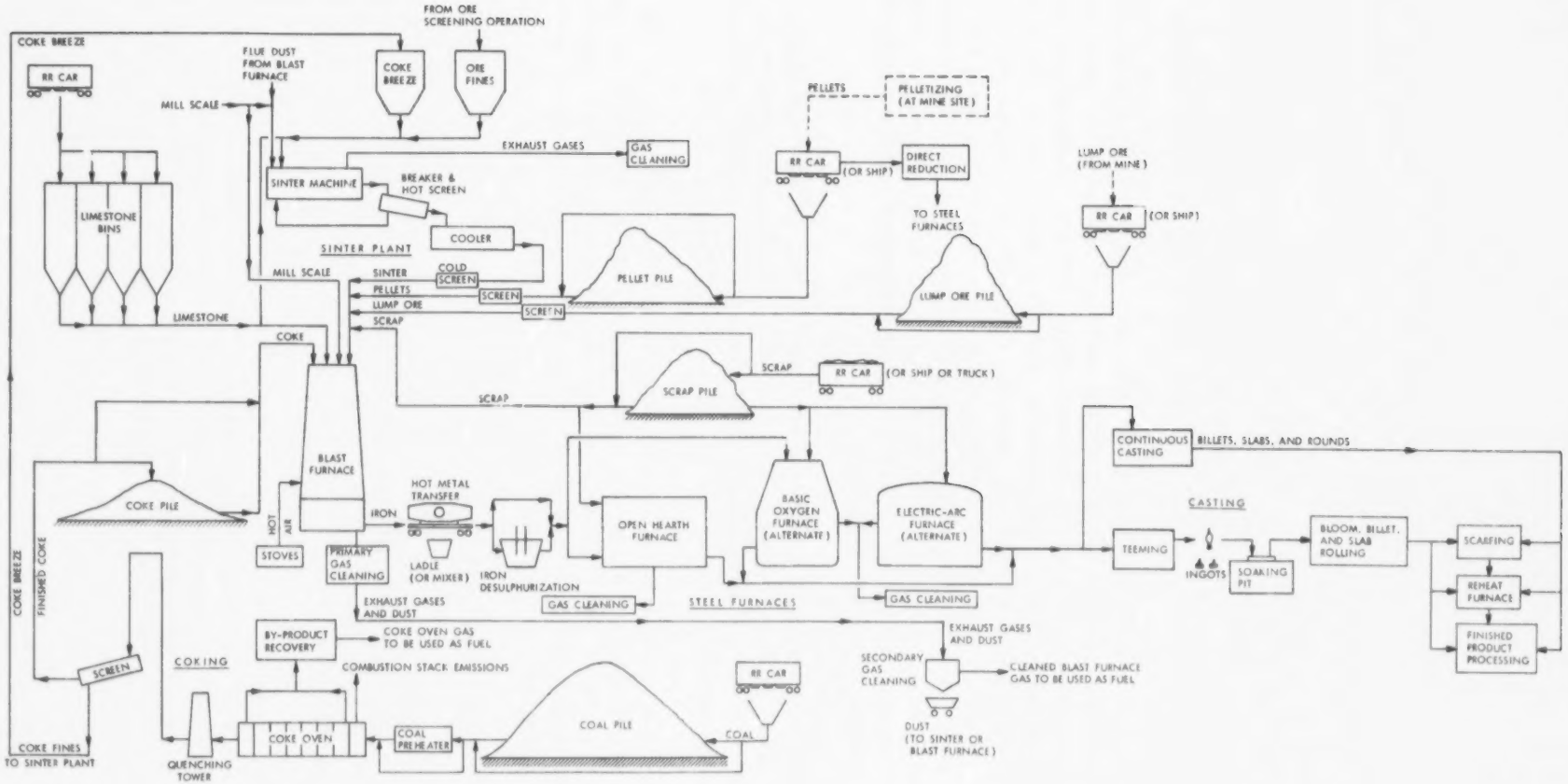


FIGURE 1 - GENERAL FLOW DIAGRAM FOR THE IRON AND STEEL INDUSTRY.

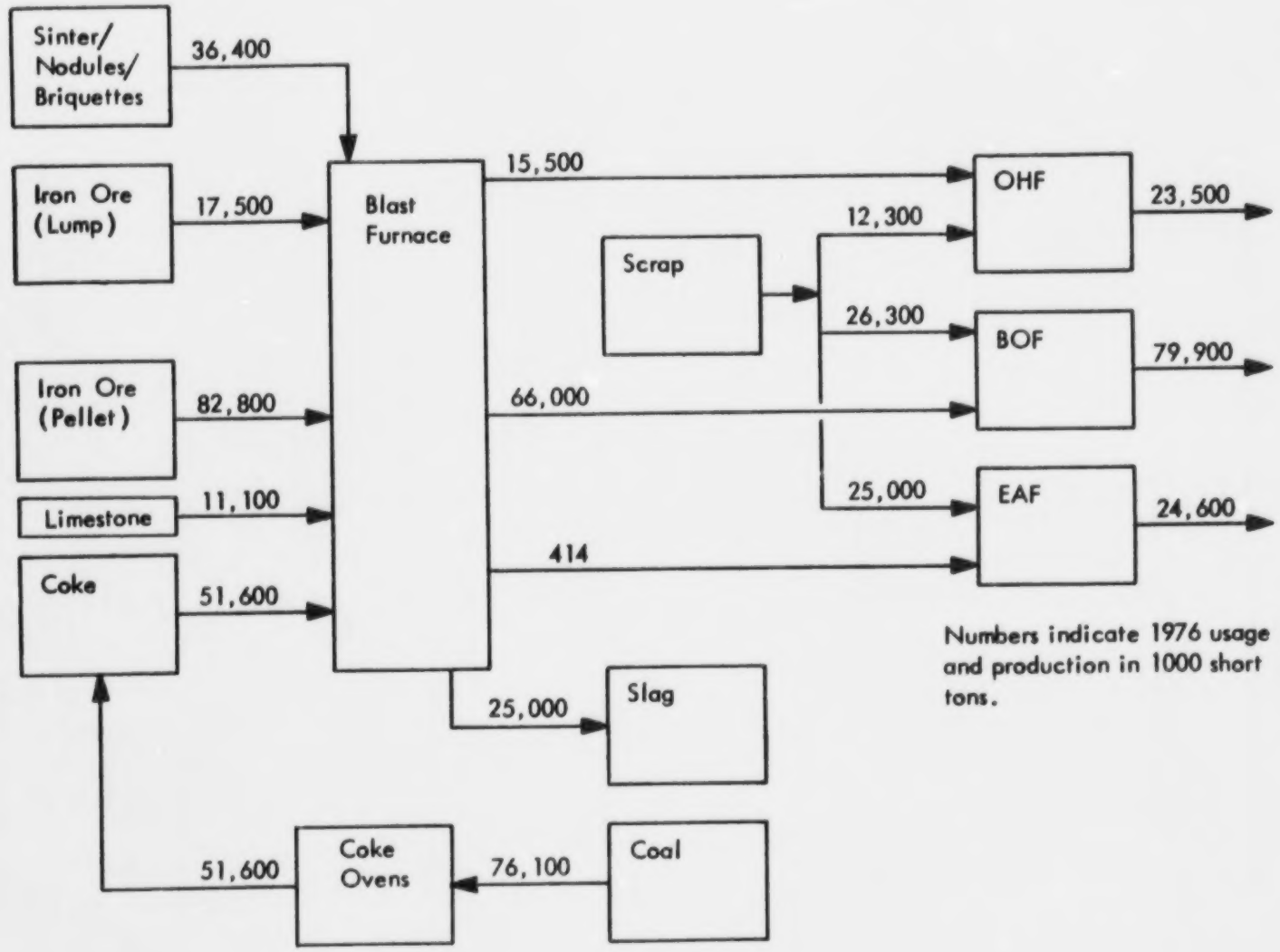


Figure 2. 1976 Iron and steel industry material flows.[3,4/]

## TABLE 1. PARTICULATE EMISSION SOURCES IN THE IRON AND STEEL INDUSTRY

| Process equipment | Process stack and fugitive emission sources | Process associated open dust sources[a/] |
|---|---|---|
| I. By-product coke ovens | * Coal Preheating<br>* Charging of coal<br>* Oven door leaks<br>* Coke pushing<br>* Wet coke quenching<br>* Oven combustion stacks<br>* Coal Preheating<br>* Topside Leaks | * Coal unloading from rail or barge<br>* Coal storage pile load-in<br>* Coal storage pile load-out<br>* Coal storage pile wind erosion<br>* Coal conveyor transfer stations |
| II. Sinter plants | * Windbox<br>* Discharge (crusher and hot screen)<br>* Cooler<br>* Cold screen | * Sinter plant input pile load-in<br>* Sinter plant input pile load-out<br>* Sinter plant input pile wind erosion<br>* Sinter plant input and output conveyor transfer stations |
| III. Blast furnaces | * Slips<br>* Cast house monitor | * Pellet, lump iron ore, coke and flux stone unloading from rail or barge<br>* Pellet, lump iron ore, coke and flux stone storage pile load-in<br>* Pellet, lump iron ore, coke and flux stone storage pile load-out<br>* Pellet, lump iron ore, coke and flux stone storage pile wind erosion<br>* Pellet, lump iron ore, coke and flux stone conveyor transfer stations |
| IV. Basic oxygen furnaces (BOFs) | * Hot metal transfer to charging ladle<br>* Scrap and hot metal charging<br>* Steel refining and melting (scrap preheat, $O_2$ blowing, turndown)<br>* Slag dumping<br>* Steel tapping<br>* Teeming | |
| V. Electric arc furnaces (EAFs) | * Scrap charging<br>* Steel refining and melting<br>* Slag dumping<br>* Steel tapping<br>* Teeming | |
| VI. Open hearth furnaces (OHFs) | * Hot metal transfer to charging ladle<br>* Scrap and/or hot metal charging<br>* Steel refining and Melting<br>* Slag dumping and steel tapping<br>* Teeming | |
| VII. Scarfers | * Hand scarfing<br>* Machine scarfing | |
| VIII. Miscellaneous combustion units | * Boilers<br>* Soaking pits<br>* Reheat furnaces | |
| IX. Vehicles | | * Traffic on paved and unpaved roads |

a/ Wind erosion of exposed plant terrain is also a source but is not shown in the above table, since it is not associated with any particular process or piece of equipment.

The by-product process is oriented toward the recovery of the gases produced during the coking cycle. The rectangular coking ovens are grouped together in a series, alternately interspersed with heating flues, called a coke battery. Coal is charged to the ovens through ports in the top, which are then sealed. Heat is supplied to the ovens by burning some of the coke gas produced. Coking is largely accomplished at temperatures of 1100° to 1150°C (2000° to 2100°F) for a period of about 16 to 20 hr. At the end of the coking period, the coke is pushed from the oven by a ram and cooled by quenching with water or via a dry quenching process.

## 2.2 SINTERING PROCESS

Sintering provides a method of agglomerating the fine-sized raw materials that are input to the blast furnace. This reduces the occurrence of "bridging" in the blast furnace and the subsequent occurrence of blast furnace slips.

Sintering is the process of fusing fine iron ore, coke, fluxstone, mill scale, coke, and flue dust at temperatures between 1300° and 1480°C (2400° and 2700°F). The sinter bed is ignited on the top surface in the furnace. The combustion front is propagated as the windboxes draw air down through the bed. The fused sinter is discharged from the end of the sinter machine where it is crushed and screened. The larger material is cooled and screened again before being input to the blast furnace.

## 2.3 IRON MANUFACTURING PROCESS

Iron is produced in blast furnaces, which are large refractory-lined chambers into which iron in the form of natural ore, or agglomerated products such as pellets or sinter, coke, and limestone are charged and allowed to react with large amounts of hot air to produce molten iron. Slag and blast furnace gases are by-products of this operation. The production of 1 unit weight of iron requires an average charge of 1.7 unit weights of iron bearing charge, 0.55 unit weight of coke, 0.20 unit weight of limestone, and 1.9 unit weight of air. Blast furnace by-products consist of 0.3 unit weight of slag, 0.05 unit weight of flue dust, and 3.0 unit weights of gas per unit of pig iron produced. The coke used in the process is produced in by-product coke ovens. The flue dust and other iron ore fines from the process are converted into useful blast furnace charge via sintering operations.

## 2.4 BASIC OXYGEN FURNACES

The basic oxygen process is employed to produce steel from a furnace charge composed, on the average, of 70% molten blast furnace metal and 30% scrap metal by use of a stream of commercially pure oxygen to oxidize the impurities, principally carbon and silicon. Cycle time for the basic oxygen process ranges from 25 to 45 min.

Most of the basic oxygen furnaces (BOF) in the United States have oxygen blown through a lance in the top of the furnace. However, the Q-BOP which is growing in use, has oxygen blown through tuyeres in the bottom of the furnace.

There is much CO produced by the reactions in the furnace. This CO can be combusted at the mouth of the furnace and then vented to gas cleaning devices as is the case with the open hood, or the combustion can be suppressed at the furnace mouth as is the case with the closed hood. The term "closed hood" is actually a misnomer since the opening is large enough to allow approximately 10% theoretical air to enter at the furnace mouth. Nearly all the Q-BOPs in the United States have closed hoods and most of the new top-blown furnaces are being designed with closed hoods. Most of the furnaces installed prior to 1975 were of the open hood design.

## 2.5 ELECTRIC ARC FURNACES

Electric arc furnaces (EAF) are used to produce carbon, alloy, and stainless steel. All the stainless steel made in the United States in 1976 was via electric arc furnaces. Cycles range from 1-1/2 to 5 hr for carbon steel and from about 5 to 10 hr or more to produce alloy steel.

The charges to an electric arc furnace is nearly always 100% scrap. Heat is furnished to melt the scrap normally via direct-arc electrodes extending through the roof of the furnace. An oxygen lance may or may not be used to speed the melting and refining process.

## 2.6 OPEN HEARTH FURNACES

In the open hearth furnace (OHF), a mixture of scrap iron and steel, and hot metal (molten iron) is melted in a shallow rectangular basin, or "hearth." Burners producing a flame above the charge provide the heat necessary for melting. The mixture of scrap and hot metal can vary from 100% scrap to 100% hot metal but 50% scrap and 50% hot metal is a reasonable industry-wide average. The process may or may not be oxygen lanced and this effects the process cycle time which is approximately 8 hr or 10 hr, respectively.

## 2.7 SCARFING

Scarfing is a method of surface preparation of semi-finished steel. A scarfing machine removes surface defects from the steel billets, blooms, and slabs before they are shaped or rolled by applying jets of oxygen to the surface of the steel which is at orange heat thus removing a thin upper layer of the metal by rapid oxidation. Scarfing is normally performed by machine on hot semi-finished steel or by hand on cold or slightly preheated semi-finished steel.

## 2.8 MISCELLANEOUS COMBUSTION SOURCES

Iron and steel plants require energy in the form of heat or electricity for every plant operation. Some energy intensive operations that produce particulate emissions on plant property are boilers, soaking pits and slab furnaces burning such fuels as coal, No. 2 fuel oil, natural gas, coke oven gas, or blast furnace gas.

In soaking pits, ingots are heated such that the temperature distribution across the cross-section of the ingots is acceptable and the surface temperature uniform for further rolling into semi-finished products such as blooms, billets, and slabs. In slab furnaces, a slab is heated before being rolled into finished products such as plate, sheet, or strip.

## 2.9 OPEN DUST SOURCE PROCESSES

As was previously stated, open dust sources include (a) vehicular traffic on paved and unpaved roads, (b) raw material handling outside of buildings, and (c) wind erosion from storage piles and exposed terrain.

Vehicular traffic consists of plant personnel and visitor vehicles, plant service vehicles, and trucks for hauling raw materials, plant deliverables, steel products, and waste materials.

Raw material is handled by clamshell buckets, bucket-ladder conveyors, rotary railcar dumps, bottom railcar dumps, front-end loaders, truck dumps, and at conveyor transfer stations. All these activities disturb the raw materials and expose the fines to the wind.

Even fine materials resting on flat areas or in storage piles are exposed to the wind. It is not unusual to have several million tons of raw material stored at a plant nor is it unusual to have in the range of 10 to 100 acres of flat exposed area at a plant. These types of sources are subject to wind erosion.

## SECTION 3.0

## EMISSION FACTORS AND SUPPORT DATA

This section presents all the known particulate emission factors (EFs) applicable to iron and steel industry sources and also the details of process operation and test methodology necessary to evaluate the reliability of the EFs. A reliability rating is given to each EF based on the following scale:

| Rating | Rating description |
|---|---|
| A | EF was based on a sound test methodology and all test methodology and process operation support data were presented in detail. |
| B | EF was based on a sound test methodology, but all test methodology and process operation support data were not presented in detail. |
| C | EF was based on questionable or unreported test methodology. |
| D | EF based on calculations and/or experienced estimate. |

Some tests are listed as unrateable. This is because no emission factor was reported or able to be calculated from the reported data. An unrateable category does not indicate that the test was not performed properly but simply indicates that there was no emission factor to rate.

### 3.1 BY-PRODUCT COKE OVENS

Particulate emissions occur during the coking operation from the following sources: (a) charging of coal, (b) oven door leaks, (c) coke pushing, (d) coke quenching, (e) oven combustion stacks, (f) coal preheating, and (g) topside leaks. The present practice is to report EFs in pounds per ton of coal so that the various sources can be compared.

#### 3.1.1 Coal Charging

One of the coal charging values presently included in the data base originated in a document which was very relevant for its time but is now technically outdated.[5] By estimates and by measurement techniques using greased plates to quantify deposition, a range of 0.1 to 2.4 lb/ton of coal charged

was acquired. There were no supportive test details listed in the document. AP-42 presently uses 1.5 lb/ton which is an average of the EFs presented in Reference 5. This EF is given a D rating.

Measurements were also performed at Bethlehem Steel's Burns Harbor Plant.[6] Measurements were taken before and after a scrubbing system. The uncontrolled emissions were measured as 0.52 lb/ton coal and the controlled emissions as 0.02 lb/ton coal. The uncontrolled emissions do not represent all the emissions from charging since emissions from the chuck door during leveling and from the coal hoppers after emptying were not captured by the system. Specific details of the tests are not available in the reference. This EF is given a C rating.

The most rigorous work in measuring the mass of charging emissions was performed under U.S. EPA Contract at the Pittsburgh Works of the J&L Steel Corporation.[141] Emission factors for charging wet coal from a Wilputte larry car for uncontrolled coal charging and from a specifically designed semi-automated sequential charging car called the AISI/EPA car were determined. Mass emissions were measured with a specialized sampling train containing an in-stack probe followed by an out-of-stack heated cyclone and filter followed by a heated line connected to a condensate trap. The train was similar to a Method 5 train although the sampling flow rate and time permitted a much smaller sample volume than is recommended by Method 5. The six emission points on the Wilputte car and the three on the AISI/EPA car were each tested three to four times. Given a charging rate of 16.7 tons of coal per charge,[142] the Wilputte car uncontrolled wet coal charging process yielded an emission factor of 0.11 lb/ton of coal while the AISI/EPA car yielded a controlled emission factor of 0.016 lb/ton of coal for sequential charging. Because of the non-isokinetic nature of the sampling, both emission factors were given a C rating.

None of the references provides definitive data, but, in the absence of such data, an average of 0.85 lb/ton coal will be used to represent uncontrolled charging emissions. This average EF is given a C rating.

### 3.1.2 Door Leaks

AISI submitted data for door leaks from Plant A which showed results of three coke-side shed tests performed when no pushing was occurring.[7] If one concludes that the emissions measured must then represent door leaks, the average door leak EF on the push side of the tested battery was 0.18 lb/ton coal (range 0.14 to 0.24 lb/ton coal). These tests were conducted before the scrubber using test method WP-50. The details of the testing effort are not known. If the value of 0.18 lb/ton coal is doubled to allow for door leaks on both sides, then a value of 0.36 lb/ton coal represents the total door leakage emissions.

A similar value was found in another coke-side shed test series.[8] The results of three tests yielded an average of 0.22 lb/ton dry coal (range 0.04 to 0.41 lb/ton dry coal based on particulate captured in the front half of the sampling train). Doubling this result to allow for door leaks on both sides yields 0.44 lb/ton dry coal.

In a coke-side shed testing effort at a third plant,[9] particulate emissions sampled during the nonpushing cycle ranged from 0.20 to 0.52 lb/ton dry coal with an average over three tests of 0.36 lb/ton dry coal. These values are based on particulate collected in the front half of the sampling train. Assuming that the nonpushing emissions were mainly comprised of door leaks and allowing for leaks on the other side of the battery, the emissions from door leaks averaged 0.72 lb/ton dry coal.

A factor of 0.5 lb/ton dry coal represents the average door leak EF. Unfortunately, the percent of doors leaking is not known for these tests so that application to other batteries is difficult. This average EF is given a B rating.

### 3.1.3 Coke Pushing

The test data for coke pushing currently available in the data base are shown in Table 2. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are five A-rated EFs, fourteen B-rated EFs and six C-rated EFs in Table 2.

### 3.1.4 Coke Quenching

The test data for coke quenching currently available in the data base are shown in Table 3. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are four A-rated EFs and five C-rated EFs in Table 3.

The reasons for the large differences shown in Table 3 between the A-rated quench test results at Dofasco's Hamilton, Ontario, plant and those at U.S. Steel's Lorain Works are currently the topic of much debate. There are five hypothesized independent variables which may explain the wide variation in emission factor measurements:

1. The vertical speed of the combined air and water vapor mixture,
2. The water application technique,
3. The total suspended solids in the quench water,
4. The amount of volatiles remaining in the coke, and
5. The existence and design of baffles.

| Average emission factor[b] (lb/ton coal) | E.F. reliability | Company/ location | Battery designation | Test date | Oven height (ft) | Tons of coke/ push[b] | Coke quality |
|---|---|---|---|---|---|---|---|
| 2.0 (Total emissions from | B | Northwest Indiana | a/ | 12/77 and | 12 | a/ | Green |
| 0.7 pushing as measured | B | | | 4/78 | | | Clean |
| 1.5 directly over car) | B | | | | | | Overall |
| 0.49 | C | Bethlehem Steel, Burns Harbor, Indiana | No. 1 | 10/74 | 20 | 23.5 | Moderate to Green |
| 0.68 | B | | No. 1 | 11/74 | 20 | 23.5 | a/ |
| 0.69[e]-Suspended emissions | A | | No. 1 | 3/75 | 20 | 22-24 | a/ |
| 0.45 - Dustfall bucket catch from all push side operations | C | | | | | | |
| 0.55[e] without sprays | A | | No. 1 | 3/76-4/76 | 20 | 23.5 | a/ |
| 0.39[e] with sprays | A | | | | | | |
| 1.4[e,f] without sprays | B | | | | | | |
| 1.2[e,f] with sprays | B | | | | | | |

| Process parameters | | | | Test methodology | | | | | Average measured concentration (gr/dscf) |
|---|---|---|---|---|---|---|---|---|---|
| Coke facility | Emission capture system | Gas flow rate (dscfm) | Gas temp. (°F) | Sampling methodology | No. of runs | No. of pushes/ run | Sample time (min) | Percent isokinetic | |
| Open | None | 175,400[c]/ | 232[d]/ (81-534) | High-volume (43 scfm) | 39 | 1 | a/ | a/ | 1.44 |
| Open | | 210,400[c]/ | 117 (71-167) | isokinetic sampler at | 25 | 1 | a/ | a/ | 0.787 |
| Overall | | 186,400 (50,000 - 749,000) | 191 (71-534) | single pt suspended in center of plume. Used 8 in. x 10 in. glass fiber filter. Cup anemometer for velocity measurements. | 64 | 1 | a/ | a/ | 1.18 |
| Operate Green | Coke-side shed | 171,000-308,000 | 160 | Andersen in-stack impactor in duct leading to collector. | 3 - during peak emissions | 1-3 | 2-6 | a/ | 0.143 |
| | Coke-side shed | 171,000-308,000 | 115-170 | Alundum Thimble-ASTM method in duct leading to collector. No condensate trap. | 2 - during peak emissions | 10 | 20 | a/ | 0.18 |
| | Coke-side shed; 85% capture efficiency | 268,000-Continuous sampling; 257,000-sampling during peak emissions | a/ 124 | EPA Method 5 in duct leading to collector. | 3 - continuous 3 - during peak emissions | 23-25 20 | 288 60 | a/ a/ | 0.054 0.19 |
| | Coke-side shed; 85% capture efficiency | a/ | a/ | EPA Method 5 in duct leading to collector | 4- without sprays; 15- with sprays | 8 | a/ | a/ | a/ |

TABLE 2. SUMMARY OF EMISSION FACTORS FOR COKE PUSHING OPERATIONS

| ercent okinetic | Average measured concentration (gr/dscf) | Average emission factor (lb/ton coal) | Comments | Reference |
|---|---|---|---|---|
| a/ | 1.44 | 2.0 (0.09-9.0) | Cross-sectional shape of plumes determined with 2 motion picture cameras. | 10 |
| a/ | 0.787 | 0.7 (0.05-2.0) | | |
| a/ | 1.18 | 1.5 (0.05-9.0) | | |
| a/ | 0.145 | 0.49 | Tests by Bethlehem Steel Corporation Research Department. Neglected probe losses. | 11 pp. 7,11,27 |
| a/ | 0.186 | 0.68 | Tests by Bethlemen Environmental Quality Control Division. 10 pts sampled per run. | 11 pp. 7,11,32-34 |
| a/ | 0.054e/ | 0.69e/ | Tests by Clayton Environmental Consultants. Suspended emission factor includes fugitive and shed captured particulate. | 8 p.63 and 12 p. 3-25 |
| a/ | 0.19e/ | | | |
| a/ | a/ | 0.55e/ Without sprays; 0.39e/ With sprays | Special tests to determine effects of water sprays as control. | 13 |

| Average emission factor[b] (lb/ton coal) | E.F. reliability | Company/ location | Battery designation | Test date | Oven height (ft) | Tons of coke/ push[b] | Coke quality |
|---|---|---|---|---|---|---|---|
| 0.25[e] Suspended emissions<br>1.1 Dustfall bucket catch from all push side operations. | A<br>C | Great Lakes Carbon St. Louis, Missouri | South | 4/75 | 11 | 10.5 | [a] |
| 2.3[e] Total uncontrolled emissions from pushing as measured directly over car. | A | Ford Motor Company, Steel Division Dearborn, Michigan | A | 6/24/75 to 7/16/75 | 13 | 12 | Avg. between green and clean. |
| 0.29 | B[g] | Company A (AISI Data) | [a] | 9/75-11/75 | [a] | 11.3 | [a] |
| 0.26 | B[g] | Company A (AISI Data) | [a] | 2/76-3/76 | [a] | 11.3 | [a] |
| 0.4[e] | C | Company B (AISI Data) | No. 3 | 12/73 | [a] | 24 | [a] |
| 0.024[e] | C | Company B (AISI Data) | No. 3 | 12/73 | [a] | 24 | [a] |
| 14.4[e] Lb/push | B | CF&I Pueblo, Colorado | B, C, D | 8/10/76 to 8/17/76 | [a] | [a] | [a] |

| Process parameters | | | Test methodology | | | | | Average measured concentration (gr/dscf) |
|---|---|---|---|---|---|---|---|---|
| Emission capture system | Gas flow rate (dscfm) | Gas temp. (°F) | Sampling methodology | No. of runs | No. of pushes/ run | Sample time (min) | Percent isokinetic | |
| Coke-side shed; 91% avg. capture efficiency | 119,000-132,000 | 69-85 | Modified EPA Method 5 in duct leading to collector. | 3 | 10-15 | 192-288 pushing cycle 168-192 non-pushing cycle | 99.9-102.9 | 0.017[e] pushing cycle |
| Travelling hood fitted directly over car. | 77,000-82,800 | 130-209 | Modified EPA Method 5 in duct leading to scrubber. | 9 | 16 or 24 | 16 or 24 | 100-108.6 | 1.67[e] |
| Coke-side shed | 175,100 | 81 | WP-50 in duct leading to collector | 28 | 8 | 24 | [a] | 0.063 |
| Coke-side shed | 168,900 | 113 | ("EPA-approved" in duct leading to collector) | 4 | 24 | [a] | [a] | 0.060 |
| Enclosed coke car & guide to venturi scrubbers via stationary main. | 61,300 | 118 | ASTM PTC-21 in duct leading to east and west scrubbers. | 6 | 7-13 | 28-78 | [a] | 0.16[e] |
| Same as above | 66,500 | 108 | ASTM PTC-21 in stacks exiting east and west scrubbers. | 6 | 7-13 | 28-78 | [a] | 0.071[e] |
| [a] | 52,400 scfm | 254 | Single point sample through probe suspended in the plume. Sampled at 45-61 scfm. | 12 | 1 | 14-30 sec | [a] | 1.852 gr/scf |

TABLE 2. (Continued)

| Percent isokinetic | Average measured concentration (gr/dscf) | Average emission factor (lb/ton coal) | Comments | Reference |
|---|---|---|---|---|
| 99.9-102.9 | 0.017[e] pushing cycle | 0.25[e] suspended<br>1.1 dustfall | Each sample taken at 20 pts in duct. Emission factor includes uncaptured fugitive and shed-captured particulate for pushing only. | 9 - page 47 and 12 - page 3-25. |
| 100-108.6 | 1.67[e] | 2.3[e] | Hood capture efficiency estimates ranged from 32 to 80%. Scrubber removed 99.3% of what was captured. | 14 - pp. 11, 98, 182, 220 |
| [a] | 0.063 | 0.29 | | 15 |
| [a] | 0.060 | 0.26 | | 15 |
| [a] | 0.16[e] | 0.4[e] | Unclear how testing east and west scrubbers coincides with pushing process. | 16 - p. 4 |
| [a] | 0.071[e] | 0.024[e] | Unclear how testing east and west scrubbers coincides with pushing process. | 16 - p. 4 |
| [a] | 1.852 gr/scf | 14.4[e] lb/push | Plume cross-sectional area determined photographically. Plume temperature measured at single point with a hot wire anemometer. | 136 |

| Average emission factor[b] (lb/ton coal) | E.F. reliability | Company/ location | Battery designation | Test date | Proc: Oven height (ft) | Proc: Tons of coke/ push[b] | Proc: Coke quality |
|---|---|---|---|---|---|---|---|
| 0.34[e] | B | Bethlehem Steel, Burns Harbor, Indiana | No. 1 | 7/74 | 20 | 23.5 | [a] |
| 0.43[e] | B | Bethlehem Steel, Burns Harbor, Indiana | No. 1 | 7/74 | 20 | 23.5 | [a] |
| 0.56 (front and back half of sampling train) | B | Bethlehem Steel, Burns Harbor, Indiana | No. 1 | 7/74 | 20 | 23.5 | [a] |
| 0.53 | B | Bethlehem Steel, Burns Harbor, Indiana | [a] | [a] | [a] | [a] | [a] |
| 0.48 - dustfall | C | Bethlehem Steel, Burns Harbor, Indiana | [a] | [a] | [a] | [a] | [a] |
| 0.32[e] | B | P | Battery C | 3/75 | [a] | [a] | [a] |

[a] Reference provides insufficient data or corroboration of data.
[b] Used 0.7 tons coke per ton of coal as conversion where necessary.
[c] Average for 66 tests.
[d] Average temperature for 33 tests.
[e] Based on particulate collected in front half of sampling train.
[f] Includes 1.25 lb/ton coke for tests without sprays and 1.1 lb/ton coke for tests with sprays a
[g] AISI - compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

| Process parameters | | | Test methodology | | | | Average measured concentrat |
|---|---|---|---|---|---|---|---|
| ke ity | Emission capture system | Gas flow rate (dscfm) | Gas temp. (°F) | Sampling methodology | No. of runs | No. of pushes/ run | Sample time (min) | Percent isokinetic | (gr/scf) |
| / | Coke-side shed | a/ | a/ | EPA train with sampling at a single point | 2 | 8-12 | 16-24 | a/ | a/ |
| / | Coke-side shed | a/ | a/ | EPA train with full Method 5 multipoint traverse | 2 | 8-12 | 16-24 | a/ | a/ |
| / | Coke-side shed | a/ | a/ | Modified ASTM train with out-of-stack filter | 7 | 8-12 | 16-24 | a/ | a/ |
| / | Coke-side shed | a/ | a/ | ASTM sampling train | 23 | 8-10 | 16-20 | a/ | a/ |
| / | Coke-side shed | a/ | a/ | a/ | a/ | a/ | a/ | NA | NA |
| / | Coke-side shed | a/ | 100 | Method 5 | 2 | 8 | 24 | a/ | 0.01 |

rs as determined by dustfall buckets.

TABLE 2. (Concluded)

| Percent isokinetic | Average measured concentration (gr/scf) | Average emission factor (lb/ton coal) | Comments | Reference |
|---|---|---|---|---|
| a/ | a/ | 0.34e/ | Emission factor represents emissions captured by shed | 17 |
| a/ | a/ | 0.43e/ | Emission factor represents emissions captured by shed | 17 |
| a/ | a/ | 0.56 | Emission factor represents emissions captured by shed | 17 |
| a/ | a/ | 0.63 | Emission factor represents emissions captured by shed | 12 p. 3-25 |
| NA | NA | 0.48 | Emission factor represents emissions settling on ground in shed | 12 p. 3-25 |
| a/ | 0.016 | 0.32e/ | In stack after scrubber with scrubber off | 12 p. 3-25 |

| Average emission factor (lb/ton coal) | E.F. reliability | Company/ location | Test date | Process parameters: Tower dimensions at sampling level | Process parameters: Tons of coal/ hr | Process parameters: Exhaust flow rate (dscfm) | Process parameters: E |
|---|---|---|---|---|---|---|---|
| 1.4 + 0.00018 x TDS[b,e] / 1.4[d] - clean water tests 2.6[d] - dirty water tests | A | U.S. Steel Lorain, Ohio | 8/76 | Tapered, cylindrical 14 ft ID at 100 ft level | 41-55 | 181,900 | |
| 0.7[c] | C | Bethlehem Steel Lackawanna, New York | 4/74 | 16 ft x 16 ft | 149 | 382,300 wet scfm | 14 |
| 0.44 | C | France | a/ | a/ | a/ | a/ | a/ |
| 0.40 | C | Poland | a/ | a/ | a/ | a/ | a/ |
| 0.25[d] | A | Dofasco Hamilton, Ontario | 8/77 | 18 ft x 37 ft | 16T coal quench | 152,000-308,400 | 15 |
| 0.21[d] | A | Dofasco Hamilton, Ontario | 8/77 | 18 ft x 37 ft | 16T coal quench | 168,100- | 15 |
| 0.23[d] | A | Dofasco Hamilton, Ontario | 8/77 | 18 ft x 37 ft | 16T coal quench | 149,300-278,700 | 15 |
| 0.32 | C | U.S. Steel Clairton, Pa. | 12/67 | 15 ft x 15 ft | 186 | 391,000 wet scfm | 15 |
| 0.04 | C | U.S. Steel Clairton, Pa. | 12/67 | 15 ft x 15 ft | 186 | 391,000 wet scfm | 15 |

a/ Reference provides indufficient data on corroboration of data.
b/ TDS = Total dissolved solids in quench water in parts per million by mass.
c/ Unclear whether value is based on particulate collected in front half of sampling trai halves combined.
d/ Based on particulate collected in front half of sampling train.
e/ Based on particulate collected in front and back halves of sampling train.

| meters | | | Test methodology | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| haust w rate scfm) | Exhaust temp. (°F) | Gallons $H_2O$ per quench | Sampling methodology | Sampling location | Sample No. of runs | Sample time/ run (min) | No. of quenches per run | Percent isokinetic | (gr/d |
| ,900 | a/ | 6,000-12,000 | High volume, 2 cfm singlepoint sampling using EPA Method 5 train with pre-cyclone. | After baffles | 25 | Only during quench (2 to 3 min each) | 4 | 91.1-109.5 | a/ |
| ,300 scfm | 142 | a/ | Single point sampling using EPA Method 5 sampling train | After baffles with sprays | 6 | About 3 min per quench. | 18 | 67-77 | 0.19 |
| | a/ | a/ | Greased disks | a/ | a/ | a/ | a/ | NA | a/ |
| | a/ | a/ | a/ | a/ | a/ | a/ | a/ | a/ | a/ |
| ,000-,400 | 155 | a/ | High volume, 2 cfm sampling at 2-6 points using cyclone and heated probe in the tower and heated filter outside the tower followed by condensate trap | 5 ft above baffles | 9 | 9-14 | 6 | 92-107 | 0.061 |
| ,100- | 155 | a/ | Same as above | 5 ft above baffles | 2 | 11-13 | 6 | 106-108 | 0.065 |
| ,300-,700 | 155 | a/ | Same as above | 5 ft above baffles | 6 | 6-13 | 3-6 | 81-108 | 0.061 |
| ,000 scfm | 150 | 4,000 | Greased plate | In tower with no baffles | a/ | a/ | a/ | NA | a/ |
| ,000 scfm | 150 | 4,000 | Greased plate | In tower with 45-degree baffles spaced 1-1/2 to 3 in. apart. Baffles are washed once per shift with sprays. | a/ | a/ | a/ | NA | a/ |

pling train or in front and back

TABLE 3. SUMMARY OF EMISSION FACTORS FOR COKE QUENCHING OPERATIONS

| Percent isokinetic | Average measured concentration (gr/dscf) | Average measured concentration (lb/hr) | Average emission factor (lb/ton coal) | Comments | References |
|---|---|---|---|---|---|
| 91.1-109.5 | a/ | a/ | 1.4 + 0.00018 x TDS[b,e] | E.F. determined from best-fit line; 12 clean water tests and 13 dirty water tests. | 18,19 |
| 67-77 | 0.19[c] | 101.9[c] | 0.7[c] | Sampled north quench tower handling mainly Battery 9 coke ovens. | 20 |
| NA | a/ | a/ | a/ | Estimate. | 5, p. 6 |
| a/ | a/ | a/ | a/ | Also contains emissions from coke pushing. | 5, p. 19 |
| 92-107 | 0.0613[d] | 3.965[d] | 0.25[d] | Using normal recycle water. | 21 |
| 106-108 | 0.0655[d] | 3.417[d] | 0.21[d] | Using normal recycle water with baffle sprays operating. | 21 |
| 81-108 | 0.0611[d] | 3.739[d] | 0.23[d] | Using once through bay water. | 21 |
| NA | a/ | 6 lb/quench | 0.32 | | 22 |
| NA | a/ | 0.75 lb/quench | 0.04 | | 22 |

Additional source testing is required to develop an equation relating emissions to the independent variables.

### 3.1.5 Coke Oven Battery Combustion Stacks

The test data for coke oven battery combustion stacks currently available in the data base are shown in Table 4. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are 21 B-rated EFs, four C-rated EFs, and one unrateable EF in Table 4.

### 3.1.6 Coal Preheaters

Some limited data exist on emissions from Cerchar coal preheaters.[135] Uncontrolled emissions of total particulate were measured during 18 tests at one plant and ranged from 5.3-8.8 lb/ton coal with an average of 7.0 lb/ton coal. Controlled emissions of total particulate were measured during 18 tests at Venturi scrubber outlets and ranged from 0.25-1.82 lb/ton coal with an average of 0.65 lb/ton coal. The original testing reports were not available to identify the test methodology; consequently, the values are C-rated.

## 3.2 BLAST FURNACES

Emissions occur during the production of iron when blast furnaces slip and when emissions escape the cast house monitor.

### 3.2.1 Slips

Slips occur when a strata of the material charged to a blast furnace does not settle with the input material below it, thus leaving a gas-filled space between the two portions of the charge. When this unsettled strata of charge collapses, the displaced gas may cause the top gas pressure to increase above the safety limit, thus opening a counterweighted bleeder valve which is open to the atmosphere.

The only EFs available to quantify slip emissions were estimated by Battelle.[26] An EF range of 0.0046 to 0.046 lb/ton of hot metal reported by the Battelle researchers was estimated by the following method.

The amount of dust emitted per slip was estimated by assuming that the slip-induced dust loading would be 10 to 100 times the maximum normal dust loading of blast furnace off-gas, which is in the range of 7 to 30 gr/scf.[27] Therefore, 300 to 3,000 gr/scf would be contained in the slip-generated gas volume. This gas volume was quantified using the dimensions of a typical furnace (30-ft diameter) and assuming a 2-ft slip height, an actual temperature of 927°C, and an actual pressure of 2 atm absolute. The gas volume calculated via the ideal gas law was 18,200 normal liters (643 scf). The entire volume of slip-generated gas was then assumed to be released through the

## TABLE 4. SUMMARY OF UNCONTROLLED EMISSION FACTORS FOR BY-PRODUCT COKE OVEN COMBUSTION STACKS

| Average emission factor[a] (lb/ton coal) | E.F. reliability | Company/ location | Coke battery designation | Test date | Process conditions: No. of ovens | Coal charged per oven (tons) | Coal input (tons/hr) | Fuel type[b] | Stack gas flow rate (scfm) | Stack temp (°F) | Test methodology: Sampling method | No. of runs | Percent isokinetic | Average measured concentration: gr/dscf | lb/hr | Emission factor[a] (lb/ton coal) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.35 | B | Alabama By-Products Torrant, AL | Nos. 5 and 6(common stack) | 10/75 | 54 | 17 | 57.4 | COG | 61,900 | 129 | EPA-5 | 1 | d/ | 0.038 | 20.1 | 0.35 | 23 |
| 0.12 | B | Armco | 1 | 7/73 | 31 | 18.5 | 41.6[e/] | NG | 30,500 | 445 | EPA-5/Texas | 1 | d/ | 0.019 | 5.1 | 0.12 | 23 |
| 0.21 | B | Steel | 1 | 4/75 | 33 | 18.5 | 41.6[e/] | NG | 31,870 | 499 | Compliance | 3 | d/ | 0.032 | 8.5 | 0.21 | |
| 0.06 | B | Houston, TX | 1 | 11/76 | 34 | 18.5 | 41.6 | NG | 39,350 | 414 | Method | 1 | d/ | 0.008 | 2.6 | 0.06 | |
| 0.42 | B | | 2 | 11/76 | 15 | 18.5 | 13.2 | NG | 8,550 | 431 | | 3 | d/ | 0.074 | 5.5 | 0.42 | |
| 0.36 | B | Bethlehem | 8 | 3/75 | 61[c/] | d/ | 51.4 | COG | 35,890 | 525 | State of | 1 | d/ | 0.060 | 18.5 | 0.36 | 23 |
| 0.42 | B | Steel | 8 | 3/75 | 61[c/] | d/ | 51.8 | BFG | 47,380 | 565 | Maryland | 2 | d/ | 0.053 | 21.6 | 0.42 | |
| 0.74 | B | Sparrows | 9 | 7/75 | 63[c/] | d/ | 54.8 | COG | 33,100 | 560 | Stack Test | 3 | d/ | 0.141 | 40.4 | 0.74 | |
| 0.18 | B | Point, MD | 9 | 6/75 | 63[c/] | d/ | 56.8 | BFG | 51,660 | 527 | Method | 2 | d/ | 0.024 | 10.3 | 0.18 | |
| 0.43 | B | | 10 | 6/75 | 61[c/] | d/ | 55.1 | BFG | 55,410 | 522 | | 5 | d/ | 0.050 | 23.8 | 0.43 | |
| 0.42 | B | | 11 | 6/75 | 63[c/] | d/ | 57.8 | COG | 29,110 | 576 | | 1 | d/ | 0.096 | 24.1 | 0.42 | |
| 0.90 | B | | 12 | 6/75 | 61[c/] | d/ | 57.1 | COG | 16,270 | 519 | | 3 | d/ | 0.165 | 51.2 | 0.90 | |
| 2.59[h/] | B | Bethlehem Steel Johnstown, PA | 17 | 12/75 | 77[c/] | 11.5 | 47.9 | COG | 66,300 | 576 | Pennsylvania State Method | 1 | d/ | 0.218 | 124 | 2.59 | 23 |
| 0.53 | B | Donner Hanna Coke Corporation Buffalo, NY | B | 12/73 | 36 | 12 | 28.5 | COG | 22,860 | 588 | EPA-5 | 3 | d/ | 0.077 | 15.2 | 0.53 | 23 |
| 1.31 | B | Kaiser Steel Fontana, CA | A | 9/75-1/76 | 45 | 14 | 31.5 | COG | 38,450 | 425 | EPA-5 | 47 | d/ | 0.125 | 41.2 | 1.31 | 23 |
| 0.16 | C | | D | 12/72 | 45 | 14 | 37.1 | COG | 42,500 | 270 | Gelman Filter | 2 | d/ | 0.016 | 5.8 | 0.16 | 23 |
| 0.12 | C | | E | 12/72 | 45 | 14 | 37.1 | BFG | 56,100 | 160 | with glass wool filter preceeding impingers | 1 | d/ | 0.009 | 4.3 | 0.12 | |
| 0.36 | B | Lone Star Steel Lone Star, TX | A & B (common stack) | 2/73 | 77 | 17.3 | 51.9 | COG | 37,200 | 468 | State of Texas with EPA train | 3 | d/ | 0.059 | 18.8 | 0.36 | 23 |
| 1.04 | B | National Steel Granite City, IL | B | 9/76 | 49 | 16.2 | 45.4 | COG | 28,170 | 600 | EPA-5 | 2 | d/ | 0.195 | 47.1 | 1.04 | 23 |

## TABLE 4. (concluded)

| Average emission factor (lb/ton coal) | E.F. reliability | Company/ location | Coke battery designation | Test date | Process conditions: No. of ovens | Process conditions: Coal charged per oven (tons) | Process conditions: Coal input (tons/hr) | Process conditions: Fuel type | Process conditions: Stack gas flow rate (scfm) | Process conditions: Stack temp (°F) | Test methodology: Sampling method | Test methodology: No. of runs | Test methodology: Percent isokinetic | Average measured concentration: gr/dscf | Average measured concentration: lb/hr | Emission factor (lb/ton coal) | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.67[h] | B | Shenango, Inc. Pittsburgh, PA | 2 & 3 (common stack | 7/76 | 35 | 19.8 | 77.0 | COG | 46,830 | 598 | EPA-5/State of Pennsylvania | 10 | [d] | 0.131 | 51.8 | 0.67 | 23 |
| 0.82[g] | B[e] | U.S. Steel Fairfield, AL | 3 | 8/75 | 48 | 15.2 | 45.6 | COG | 37,300 | 483 | MP-50 (thimble) | 3 | [d] | 0.117 | 37.3 | 0.82 | 23 |
| 0.46 | B | Youngstown Sheet & Tube Company Indiana Harbor, IN | 4 | 11/76 | 75 | 18.1 | 71.4 | COG | 72,940 | 527 | EPA-5 | 3 | [d] | 0.052 | 32.6 | 0.46 | 23 |
| 0.7 | C | Company D (AISI data) | [d] | 4/75 | [d] | [d] | [d] | [d] | 55,000 | 581 | [d] | 10 | [d] | 0.194 | 40.3 | 0.7 | 24 |
| 0.08 | B[e] | Company A (AISI data) | No. 2 | 5/75 | [d] | [d] | [d] | [d] | 70,325 | 565 | MP-50 | 4 | [d] | 0.008 | 5.25 | 0.08 | 25 |
| 0.8 | C[e] | Company D (AISI data) | [d] | 4/75 | [d] | [d] | [d] | [d] | 66,100 | 499 | [d] | 10 | [d] | 0.210 | 42.8 | 0.8 | 24 |
| [d] | [d] | CF&I Pueblo, CO | D | 6/78 | 31 | [d] | [d] | [d] | 17,420 | 441 | EPA-5 | 3 | 96.9-108.4 | 0.00650 | 0.98 | [d] | 139 |

[a] "Front half" particulate only.
[b] COG: coke oven gas; BFG: blast furnace gas; NG: natural gas.
[c] Exact number of ovens in operation during testing not known.
[d] Reference provides insufficient data or corroboration of data.
[e] AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
[f] Reported as 56-60 tons of coal/hr in a 10/11/76 letter from Bill Benzer to Peter Westlin.
[g] Sample taken only during charging period.
[h] May include particulate captured in front and back halves of train.

dirty-gas bleeder valve. Thus, the quantity of dust emitted per slip would range from 27.6 to 276 lb.

Of the total of 135 blast furnaces operating in the United States in 1974 to 1975, it was assumed that 22 were "problem" furnaces which averaged 30 slips per month. The remaining 113 furnaces were assumed to average four slips per month. Therefore, the total number of slip-induced bleeder valve emissions in the United States in 1974 was 13,350. Using the 27.6 to 276 lb/slip range and the 1974 net hot metal production rate of $79.9 \times 10^6$ tons, the EFs for slip-induced emissions are found to range from 0.0046 to 0.046 lb/ton of hot metal produced. The document qualifies this as a first attempt order of magnitude calculation.

### 3.2.2 Cast House Monitor

The test data for cast house emissions currently available in the data base are shown in Table 5. Average EFs and their reliabilities along with process parameters and test methodology are presented. There is one A-rated EF, five B-rated EFs, and four C-rated EFs in Table 5.

## 3.3 SINTERING

Emissions occur at several points in the sintering process. The points of particulate generation are (a) the windbox, (b) the discharge (sinter crusher and hot screen), (c) the cooler, and (d) the cold screen. In addition to these sources, there are in-plant transfer stations which generate emissions and can be controlled by localized enclosures. All the above sources, except the cooler, are normally vented to one or two control systems.

The main problem with the EFs related to sintering compiled in Table 6 is that the sources contributing to the factor are not delineated in many cases. There are fifteen A-rated EFs in Table 6, twenty-seven B-rated EFs, eight C-rated EFs, and ten unrateable factors.

## 3.4 BASIC OXYGEN FURNACES

There are several sources of particulate emissions in the basic oxygen furnace steelmaking process. The emission sources are (a) emissions from the furnace mouth during refining collected by local full (open) or suppressed (closed) combustion hoods, (b) hot metal transfer to charging ladle, (c) charging scrap and hot metal, (d) dumping slag, and (e) tapping steel.

Table 7 lists EFs from several of the above sources. The roof monitor emissions are a composite of the portion of charging, tapping, slagging, and hot metal transfer emissions that escape to the atmosphere.

| Average Emission factor (lb/ton hot metal) | E.F. reliability | Company/ location | Furnace designation | Test date | Process parameters: Tons hot metal/ cast | Duration of cast (min) | Exhaust rate (scfm) | Gas temp. ($^{o}$F) | Emission capture system |
|---|---|---|---|---|---|---|---|---|---|
| 0.1[c] | B | Bethlehem Steel, Bethlehem, Pa. | E | 9/76 | a | a | 83,500 | 111 | < 75% capture |
| 0.26[c] | B | | | | a | a | 283,700 | 108 | 75-90% capture |
| 0.25[c] | B | | | | a | a | 144,100 | 125 | 80-95% capture |
| 0.78[c] | A | Dofasco, Hamilton, Ontario Canada | No. 1 | 8-11/76 | 277 | 37 | 308,300 | 134 | 100% open fan setting |
| 0.48[c] | C | | No. 1 | | 321 | 32 | 293,600 | 140 | 70% open fan setting |
| 0.68[c] | C | | No. 1 | | 283 | 36 | 208,100 | 155 | 40% open fan setting |
| 0.20[c] | B | Bethlehem Steel, Johnstown, Pa. | E | 10/76-11/76 | 180 | 33 | 289,900 | 82 | Total cast house evacuation to baghouse |
| 0.25 | C | CF&I, Pueblo, Colorado | a | a | a | a | a | a | a |
| 0.52 | C | Dofasco, Hamilton, Ontario Canada | No. 1 | 8/76-11/76 | a | a | 300,000 acfm | a | Building evacuation to baghouse |
| 0.31 | B[b] | Bethlehem Steel, Sparrows Point, Md. | J | 11/76-12/76 | 391 | 32-70 | 458,400-695,200 | 95 | None |

a/ Reference provides insufficient data or corroboration of data.

b/ AISI - compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

c/ Based on particulate collected in front half of sampling train.

TABLE 5. SUMMARY OF EMISSION FACTORS FOR BLAST FURNACE C

| Emission capture system | Test methodology: Sampling methodology | No. of runs | Sample time/run (min) | Percent Iso-kinetic | Average Measured concentration (gr/scf) | Average Measured concentration (lb/hr) | Average Emission factor (lb/ton hot metal) | Comments |
|---|---|---|---|---|---|---|---|---|
| < 75% capture | EPA Method 5, Sampled in duct after hood and before any control device | 3 | 30-40 | a/ | 0.050c/ | 35.5c/ | 0.10c/ | Capture efficiency ba visual observation of hood collection syste represents only local tured taphole and tro emissions. |
| 75-90% capture | | 3 | 35-65 | a/ | 0.041c/ | 98.5c/ | 0.26c/ | |
| 80-95% capture | | 3 | 31-35 | a/ | 0.097c/ | 120 | 0.25c/ | |
| 100% open fan setting | EPA Method 5, Sampled in duct leading to bag-house | 2 | 35 | 101 | 0.142c/ | 368c/ | 0.78c/ | Total cast house evac One test per cast. |
| 70% open fan setting | | 2 | 22 | 106-111 | 0.126c/ | 299c/ | 0.48c/ | |
| 40% open fan setting | | 2 | 33 | 111-116 | 0.200c/ | 326c/ | 0.68c/ | |
| Total cast house evac-uation to baghouse | EPA-5 | 19 | 33 | a/ | 0.029c/ | 60.9c/ | 0.20c/ | One test per cast. Sampling in duct lead to baghouse. |
| a/ | Time lapse photography | a/ | a/ | a/ | a/ | a/ | 0.25 | Study done by Celesco Ind. (Report No. 156). |
| Building evacuation to baghouse | Weight of particulate captured by the baghouse | | | | | | | Does not include weigh of emissions passed by baghouse. |
| None | Hi-Vols sus-pended in bays of the roof monitor | 10 | 32-70 | a/ | 0.028 | 157 | 0.31 | |

ion, OAQPS.

TABLE 5. SUMMARY OF EMISSION FACTORS FOR BLAST FURNACE CAST HOUSE OPERATIONS

| Test methodology | | | | Average Measured concentration | | Average Emission factor (lb/ton hot metal) | Comments | Reference |
|---|---|---|---|---|---|---|---|---|
| ...gy | No. of runs | Sample time/run (min) | Percent Iso-kinetic | (gr/scf) | (lb/hr) | | | |
| ...d 5, ...n duct ...d and ...y ...evice | 3 | 30-40 | a/ | 0.050c/ | 35.5c/ | 0.10c/ | Capture efficiency based on visual observation of canopy hood collection system. EF represents only locally captured taphole and trough emissions. | 28; 29, pp. 52-53 |
| | 3 | 35-65 | a/ | 0.041c/ | 98.5c/ | 0.26c/ | | |
| | 3 | 31-35 | a/ | 0.097c/ | 120 | 0.25c/ | | |
| ...od 5, ...in duct to bag- | 2 | 35 | 101 | 0.142c/ | 368c/ | 0.78c/ | Total cast house evacuation. One test per cast. | 29 p. 45, p. C-1ff |
| | 2 | 22 | 106-111 | 0.126c/ | 299c/ | 0.48c/ | | |
| | 2 | 33 | 111-116 | 0.200c/ | 326c/ | 0.68c/ | | |
| | 19 | 33 | a/ | 0.029c/ | 60.9c/ | 0.20c/ | One test per cast. Sampling in duct leading to baghouse. | 29 p. 52,53, D-1 |
| ...se ...phy | a/ | a/ | a/ | a/ | a/ | 0.25 | Study done by Celesco Ind. (Report No. 156). | 29 p. 52 |
| ...f ...ate ... by ...ouse | | | | | | | Does not include weight of emissions passed by baghouse. | 29 pp. 45-46 |
| ...sus- ...in ...the ...nitor | 10 | 32-70 | a/ | 0.028 | 157 | 0.31 | | 29 p. 52; 30 |

| Average emission factor (lb/ton sinter) | Emission factor reliability | Source | Company/ location | Test date | Process production rate | Proc flo (d |
|---|---|---|---|---|---|---|
| 10.8[b] (leaving grate) | B | Uncontrolled windbox exhaust stack | Company D (AISI data) | 3/75 | 1,368-2,369 tons sinter/day | 140,00 |
| 6.8[b] | B | Uncontrolled strand discharge emissions | Company D (AISI data) | 3/4-5/75 | 1,500-2,340 tons sinter/day | 34,000 |
| 11.8[b] (leaving grate) | B | Uncontrolled windbox exhaust stack | Company C (AISI data) | 10/1/69 | 150 tons sinter/hr | 165,00 |
| 1.0[b] | B[e] | Controlled windbox exhaust stack | Company C (AISI data) | 3/70-4/70 | 150 tons sinter/ hr | 125,00 wet sc |
| 8.7[b] | A[e] | Uncontrolled emissions from unspecified source (assume windbox) | Company N (AISI data) | 10/75-11/75 | 113-132 tons sinter/hr | 240,00 |
| 1.9[b] (avg of all tests) | C[e] | Controlled emissions from unspecified source (assume windbox) | Company N (AISI data) | 10/75-11/75 | 113-132 tons sinter/hr | 239,00 |
| 2.2[b] (avg of isokinetic tests) | A | | | | | |
| 0.55[b] | C | (Assume controlled windbox)[a] | Company N (AISI data) | 4/18-25/74 | 10,604-11,167 tons sinter/day | 256,00 |
| 107[c] | A | Uncontrolled emissions from windbox | Company P (AISI data) | 12/29/72 | 1,350 tons sinter/day | 296,00 |
| 0.7[c] | A[e] | Controlled emissions from windbox | Company P (AISI data) | 12/29/72 | 1,350 tons sinter/day | 305,00 |
| 47[c] avg of 2 tests<br>32[c] avg including suspect test | B<br>B[e] | Uncontrolled emissions from unspecified source | Company P (AISI data) | 3/27/73 | 1,471 tons sinter/ day | 111,80 |
| 0.35[c] | B[e] | Controlled emissions from unspecified source | Company P (AISI data) | 3/27/73 | 1,471 tons sinter/ day | 111,00 |

| Process conditions | | Test methodology | | | |
|---|---|---|---|---|---|
| Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokineti |
| ,000-224,000 | 188-287 | In stack thimble | In windbox exhaust stack | a/ | a/ |
| 000 | 112-151 | 10 min tests- 47 mm glass fiber filter 2 hr tests- alundum thimble | In discharge stack | 10 min tests - single pt in stack 2 hr tests - 24 pt traverse | a/ |
| ,000 | 260 | Alundum thimble | In 9 ft sq duct before fan and after coarse particulate control devices. | a/ | a/ |
| ,000-135,000 scfm | 206 | Alundum thimble | In 8 ft Ø stack, 85 ft above ground and 15 ft from top | Single point in stack | a/ |
| ,000-284,000 | 102-215 | a/ | a/ | EPA Method 5 | 101-108 |
| ,000-312,000 | 128-208 | a/ | a/ | EPA Method 5 | 92-199 |
| 6,000-274,000 | 147-175 | In-stack thimble | a/ | a/ | 82-99 |
| 6,000-302,000 | 90-95 | Standard EPA-approved train | In 4 ft x 14.5 ft tile-lined plenum | Modified EPA Method 5. Each test was a traverse along a different single axis. | 108-113 |
| 5,000-308,000 | 70-73 | Standard EPA-approved train | In 8 ft Ø stack | EPA Method 5 | 99-103 |
| 1,800 acfm | a/ | a/ | Directly after bend in duct leading to baghouse | EPA Method 5(unspecified number of points in traverses) | a/ |
| 1,000 acfm | a/ | a/ | In 3 ft Ø stack 1 ft beyond fan and 2 ft from stack exit. Baghouse had 14 stacks, 1/compartment | EPA Method 5 (unspecified number of points in traverse-sampling ports 1 ft beyond fan) | a/ |

| rcent kinetic | Sampling time per run (min) | Gas flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Avg. (gr/dscf) | Emission factors Range (lb/ton sinter) | Emission factors Avg. (lb/to |
|---|---|---|---|---|---|---|---|
| | a/ | a/ | 17 | 0.082-0.196b/ | 0.135 | 5.1-19.0b/ | 10.8b/ |
| | 4 tests-2 hr each; 11 tests-10 min each | a/ | 15 | 0.97-1.96b/ gr/acf | 1.54 gr/acfb/ | 5.3-8.3b/ | 6.8b/ |
| | a/ | a/ | 6 | 0.16-0.31b/ gr/acf | 0.21 gr/acf | 8.8-17.4b/ | 11.8b/ |
| | a/ | a/ | 16 | 0.13-0.3b/ gr/wet scf | 0.21b/ | 0.64-1.5b/ | 1.0b/ |
| -108 | 90 | a/ | 10 | 0.176-1.01b/ | 0.47b/ | 3.1-18.9b/ | 8.7b/ |
| 99 | 120 | a/ | 10 | 0.043-0.17b/ | 0.11b/ | 0.83-3.8b/ | 1.9b/ |
| 99 | a/ | a/ | 2 | 0.188-0.212b/ | 0.2b/ | 0.4-0.7b/ | 0.55b/ |
| -113 | 97-133 | 0.4-0.54 | 3 | 0.4019-5.0207c/ | 2.3676c/ | 18-228c/ | 107c/ |
| 103 | 100 | 0.53 | 3 | 0.014-0.0157c/ | 0.0148c/ | 0.65-0.73c/ | 0.7c/ |
| | a/ | a/ | 2(3rd test suspect due to temporary line shut-down) | 2.9049-3.7493c/ | 3.3271c/ | 42-52c/ | 47c/ |
| | a/ | a/ | 2(3rd test suspect) | 0.02275-0.02490c/ | 0.0238c/ | 0.32-0.39c/ | 0.35 |

TABLE 6. TABLE OF EMISSION FACTORS FOR SINTER PLA

| Emission factors | | | |
|---|---|---|---|
| Range (lb/ton sinter) | Avg. (lb/ton sinter) | Comments | Reference |
| 5.1-19.0[b] | 10.8[b] | | 31 |
| 5.3-8.3[b] | 6.8[b] | Tests performed after cyclone-efficiency of 79% determined by weighing cyclone catch. This efficiency used to calculate uncontrolled emissions. | 32 |
| 8.8-17.4[b] | 11.8[b] | Tests performed after inertial trap, multiclones and policeman. Efficiency of 75% determined by unspecified method. This efficiency used to calculate uncontrolled emissions. | 33 |
| 0.64-1.5[b] | 1.0[b] | Smapled after cyclones. | 34 |
| 3.1-18.9[b] | 8.7[b] | Sampled at precipitator inlet. | 35 |
| 0.83-3.8[b] | 1.9[b] | Samples taken at ESP outlet. Five tests were well above the +10% nonisokinetic sampling tolerance. | 35 |
| 0.4-0.7[b] | 0.55[b] | | 36 |
| 18-228[c] | 107[c] | Uncontrolled emissions were observed to be the worst the plant had experienced. | 37 |
| 0.65-0.73[c] | 0.7[c] | Control consists of water spray followed by tray-type scrubber. | 37 |
| 42-52[c] | 47[c] | | 38 |
| 0.32-0.39[c] | 0.35[c] | After Mikropul baghouse. | 38 |

| Average emission factor (lb/ton sinter) | Emission factor reliability | Source | Company/ location | Test date | Process production rate | Pr |
|---|---|---|---|---|---|---|
| 98[c] most accurate<br>46[c] avg of all 4 tests | B<br>C | Uncontrolled emissions from windbox | Company P (AISI data) | 2/73 | 75 tons sinter/hr | 300 |
| 0.9[c] | B | Controlled emissions from windbox | Company P (AISI data) | 2/73 | 75 tons sinter/hr | 250 |
| 11[d] | B | Uncontrolled emissions from discharge and other unspecified sources | Company A (AISI data) | 1/71 | 3,400 tons sinter/ day | a |
| 0.05[d] | B | Controlled emissions from discharge and other unspecified sources | Company A (AISI data) | 1/71 | 3,400 tons sinter/ day | 138, |
| 0.63[b] | B | Controlled emissions from windbox | Company A (AISI data) | 5/75 | 3,600 tons sinter/ day | 288, |
| 2.6[b] (in stack) lb/ton feed<br>10.5[b] (leaving grate) lb/ton feed | B<br>B | Uncontrolled windbox (every windbox has at least an inertial collector for large particles) | Armco, Inc. Ashland, KY | 8/70-11/70 | 150 tons feed/hr (feed here includes hot recycle fines from windbox and hot screen) | a |
| a | a | Controlled windbox | Armco, Inc. Ashland, KY | 8/70-11/70 | 150 tons feed/hr | a |
| 0.03[c]<br>0.0012[b] | A<br>A | a | Inland Steel E. Chicago, IL | 7/75 | 159 tons sinter/ hr | 118, |

| Process conditions | | Test methodology | | | |
|---|---|---|---|---|---|
| Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinet |
| ,000 | 130 | EPA-approved train | In 4 ft x 14 ft scrubber inlet duct at a bend | Modified EPA Method 5 (2 tests at only a single point; 1 test using a partial traverse; 1 test using a full traverse in one direction. Temp. of probe and filter kept the same as duct gas. | a/ |
| ,000-289,000 | 100 | EPA-approved train | After tray type scrubber (assume 8 ft Ø stack) | Modified EPA Method 5 (probe and filter temp. set to coincide with flue gas temp.) | a/ |
| | a/ | Thimble | a/ | WP-50 | a/ |
| ,200 | 120 | Thimble | After baghouse | WP-50 | a/ |
| ,000 | 300 | Model EPA-2 emissions parameter analyzer by Western Precipitation Div. of Joy Manufacturing | In 153 in. Ø stack after ESP | EPA Method 5. 48 points along 2 perpendicular lines. | 87-91 |
| | a/ | Alundum thimble filter packed with fine glass wool. Wet impinger. Water trap. | Induced draft stack. After S-collector, multicyclones, and policeman. | a/ | a/ |
| | a/ | Same as above | After pilot scrubber | a/ | a/ |
| ,500 | 118 | Standard EPA sampling train | In stack after baghouse | EPA Method 5 | 98.4 |

| Percent isokinetic | Sampling time per run (min) | Gas flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Avg. (gr/dscf) | Emission factors Range (lb/ton sinter) | Emission factors Avg. (lb/ton |
|---|---|---|---|---|---|---|---|
| | 90 | a/ | 4 | 0.379-2.86c/ | 2.86 (most accurate test) c/ | 13-98c/ | 98 (mo test)c/ |
| | 90 | a/ | 3 | 0.0195-0.0388c/ | 0.0295c/ | 0.6-1.2c/ | 0.91c/ |
| | a/ | a/ | 1 | None | 5.65d/ | None | 11d/ |
| | a/ | a/ | 1 | None | 0.006d/ | None | 0.05d/ |
| 7-91 | 192 | 0.5 | 3 | 0.034-0.045b/ | 0.038b/ | 0.56-0.74b/ | 0.63b/ |
| | a/ | a/ | 40 | 0.2-0.44b/ gr/scf | 0.31b/ gr/scf | a/ | 2.6 l (in s |
| | a/ | a/ | 8 | 0.005-0.021b/ | a/ | a/ | a/ |
| .4 | 60 | 0.6 | 3 | 0.0040-0.0051c/ 0.0012-0.0016b/ | 0.0047c/ 0.0014b/ | 0.026-0.034c/ 0.0079-0.01b/ | 0.030 0.009 |

TABLE 6. (CONTINUED)

| ssion factors<br>ge<br>sinter) | Avg.<br>(lb/ton sinter) | Comments | Reference |
|---|---|---|---|
| | 98 (most accurate test)[c] | Number of traverse points in the "most accurate" test unclear. Lab analysis performed so as not to drive off condensible hydrocarbons. Report noted that Method 5 analysis produced factor of 2 lower total particulate emissions. | 39 |
| c/ | 0.91[c] | Tray-type scrubber pressure drop of 9 to 11 in. $H_2O$. Lab analysis performed so as not to drive off condensible hydrocarbons. | 39 |
| | 11[d] | Emissions from hot screen hood, sinter breaker, and two unknown sources. | 40 |
| | 0.05[d] | | 40 |
| .74[b] | 0.63[b] | | 41 |
| | 2.6 lb/ton feed (in stack) | 75% of dust leaving grate is captured by S-collectors multicyclones and policeman. Only dust emissions are reported, not oil. | 42 |
| | a/ | Concentration varies from high to low as pressure drops across scrubber was increased from 23 to 76 in. of $H_2O$. | 42 |
| 0.034[c]<br>-0.01[b] | 0.030[c]<br>0.0092[b] | 12 sample point/run; 5 min/sampling point; stainless steel probe on tests 1 and 2, glass lined probe in test 3. | 43 |

| Average emission factor (lb/ton sinter) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 4.8[c]/<br>3.8[b]/<br>lb/tons input | C | Controlled Windboxes | Bethlehem Steel<br>Johnstown, PA | 12/75 | 105 tons feed/hr (including recycl fines but exclud hearth layer) |
| [a]/ | [a]/ | Uncontrolled windbox | Armco, Inc.<br>Houston, TX | 7/71 | 1194 tons input/ day |
| [a]/ | [a]/ | Controlled windbox | Armco, Inc.<br>Houston, TX | 7/71 | 1194 tons input/ day |
| [a]/ | [a]/ | Controlled emissions (Assume windbox emissions) | Alan Wood Steel<br>Conshohocken, PA | 5/71-6/71 | [a]/ |
| 0.49[c]/ | C | Combined effluent from sinter machines 1, 2, and 3 | Alan Wood Steel<br>Conshohocken, PA | 4/74 | 73.5 tons/hr of sinter (including recycled fines) |
| 0.43[b]/<br>0.9[c]/ | B<br>B | Controlled effluent from two windboxes | Bethlehem Steel<br>Bethlehem, PA | 6/75 | 120 tons/hr of sinter/two machines |
| 0.1[b]/ | B | Controlled effluent from 4 sinter machine breakers and hot screens | Bethlehem Steel<br>Bethlehem, PA | 5/75 | 239 tons/hr of sinter/four machines |
| 0.30[b]/<br>0.41[c]/ | A<br>A | Controlled effluent from sinter draft system from machine No. 2 (Includes wind-box and discharge emissions) | Kaiser Steel<br>Fontana, CA | 6/75 | 160 tons/hr of sinter |

| Process conditions | | | Test methodology | | |
|---|---|---|---|---|---|
| rocess oduction rate | Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology |
| s feed/hr ing recycled ut excludes layer) | 184,600 | 225 | Modified EPA sampling train | In stack after Research Cottrell ESP | EPA Method 5 |
| ns input/ | a/ | a/ | Modified EPA sampling trains w/2 impingers | In inlet to pilot sized venturi scrubber | a/ |
| ns input/ | a/ | a/ | Modified EPA sampling trains w/2 impingers | In out from pilot sized venturi | a/ |
| | 2000-3000 | 123-180 | Glass probe in stainless steel housing, glass cyclone, and glass fiber filter | After hydro-clean scrubber pilot unit | Modified EPA Method 5 |
| ns/hr of (including fines) | 279,200 scfm | 87 | Standard EPA sampling train | In stack after hydro cleaners | EPA Method 5 |
| s/hr of two s | 200,300 | 268 | Modified EPA sampling train | In stack after ESP | EPA Method 5 |
| s/hr of four s | 138,100 | 237 | Modified EPA sampling train | In stack after baghouse | EPA Method 5 |
| s/hr of | 132,700 | 302 | Microchemical Specialties Co. Misco Model 7200 CM glass lined stainless steel probe and glass fiber filters | In stack after baghouse | EPA Method 5 |

| Percent isokinetic | Sampling time per run (min) | Gas flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Avg. (gr/dscf) | Emission fact Range (lb/ton sinter) |
|---|---|---|---|---|---|---|
| 105 | 120 | 0.6 | 1 | NA | 0.32c/<br>0.256b/ | NA |
| a/ | a/ | a/ | 55 | 0.02-0.33b/ gr/wet scf | 0.205b/ gr/wet scf | a/ |
| a/ | a/ | a/ | 55 | 0.003-0.0125b/ gr/wet scf | 0.003b/ gr/wet scf | a/ |
| a/ | 33-53 | 0.35-0.72 | 15 | 0.0049-0.0403b/ | 0.017b/ | a/ |
| 94.2 | 120 | a/ | 1 | NA | 0.015c/ | NA |
| a/ | 144 | a/ | 3 | 0.0203-0.0417b/<br>0.0472-0.0759c/ | 0.0301b/<br>0.0631c/ | 0.146-0.299b/<br>0.34-0.54c/ |
| a/ | 120 | a/ | 3 | 0.019-0.022b/ | 0.02b/ | 0.19-0.22b/ |
| 96.2 | 180 | 0.9 | 3 | 0.03-0.497b/<br>0.0450-0.0672c/ | 0.042b/<br>0.0578c/ | 0.21-0.38b/<br>0.31-0.52c/ |

TABLE 6. (CONTINUED)

| Emission factors | | | |
|---|---|---|---|
| Range (ton sinter) | Avg. (lb/ton sinter) | Comments | Reference |
| | 4.8c/<br>3.8b/<br>lb/tons input | Emission factor based on tonnage input and not sinter output. 12 sampling points; 10 min/sampling point. | 44 |
| | a/ | Concentrations represent only dust emissions and not condensed hydrocarbons. | 45 |
| | a/ | Pressure drops were varied between 23 and 61 in. $H_2O$ during the 55 tests. | 45 |
| | a/ | | 46 |
| | .49c/ | | 47 |
| 6-0.299b/<br>-0.54c/ | 0.43b/<br>0.9c/ | | 48 |
| -0.22b/ | 0.2b/ | | 48 |
| -0.38b/<br>-0.52c/ | 0.30b/<br>0.41c/ | | 140 |

| Average emission factor (lb/ton sinter) | Emission factor reliability | Source | Company/ location | Test date | Process production rate | Proce |
|---|---|---|---|---|---|---|
| 2.0[b] | A | Controlled effuent from windboxes. | CF&I Pueblo, CO | 6/75 | 329 ton/hr feed rate (including recycled fines) 164 ton sinter/hr | 23 |
| 2.3[c] | A | | | | | |
| 6.87[b] lb/ton feed | C | Uncontrolled effluent from windobxes. | CF&I Pueblo, CO | 6/75 | 329 ton/hr feed rate (including recycled fines) 164 ton sinter/hr | 247 |
| 6.96[c] lb/ton feed | C | | | | | |
| 0.32[b] | A | Controlled effluent gases from windboxes | Granite City Steel Division Granite City, IL | 5/75 | 102 tons/ hr of sinter | 199 |
| 0.72[c] | A | | | | | |
| [a] | [a] | Controlled emissions (source unclear). | Jones & Laughlin Steel Aliquippa, PA | 8/72 | [a] | 146 |
| [a] | [a] | Controlled emissions (source unclear). | Jones & Laughlin Steel Aliquippa, PA | 8/72 | [a] | 138 |
| [a] | [a] | Controlled effluent. Portion of windbox emissions. | Jones & Laughlin Steel Aliquippa, PA | 2/73 | [a] | 2,0 |
| 0.03 (solid part.) | C | Controlled effuent. Portion of windbox emissions. | Jones & Laughlin Steel Aliquippa, PA | 2/74 | [a] | 2,1 |
| 0.13 (solid part.) | B | Controlled effleunt. Portion of windbox emissions. | Jones & Laughlin Steel Aliquippa, PA | 4/73 | [a] | 1,6 |
| [a] | [a] | Controlled effluent from windboxes. | Jones & Laughlin Steel Aliquippa, PA | 5/75 | [a] | [a] |

| Process conditions | | Test methodology | | | |
|---|---|---|---|---|---|
| Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Pe iso |
| 232,400 | 221 | a/ | In stack after multi-clones and ESP | EPA Method 5 | 101 |
| 247,500 | 195 | a/ | In ducting before multi-clones and ESP | EPA Method 5 | 117 |
| 199,000 | 149 | Standard EPA sampling train | In stack after venturi scrubber | EPA Method 5 | 99 |
| 146,200 | 407 | | "A" Duct leading to main stack after precipitator | EPA Method 5 | 99 |
| 138,200 | 419 | | "B" Duct leading to main stack after precipitator | EPA Method 5 | 99. |
| 2,010 | 320 | Modified EPA sampling train | After precipitator | EPA Method 5 | a/ |
| 2,130 | 113 | Stainless steel probe, impingers fiberglass filter | After precipitator | a/ | a/ |
| 1,632 | 246 | Stainless steel probe, impinters (no filter) | After gravel bed | Sample taken at center point of duct | a/ |
| a/ | 351 | Standard EPA sampling train | East breeching 15 ft downstream of fan outlet & after mechanical collectors | EPA Method 5 | a/ |

| Percent isokinetic | Sampling time per run (min) | Gas flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Avg. (gr/dscf) | Emission factors Range (lb/ton sinter) | Emission factors (lb/ |
|---|---|---|---|---|---|---|---|
| 101.6 | 143 | 0.4 | 3 | 0.148-0.179[b] | 0.159[b] | 1.8-2.0[b] | 2.0[b] |
| | | | | 0.168-0.229[c] | 0.192[c] | 2.16-2.7[c] | 2.3 |
| 117 | 108 | 0.4 | 3 | 0.510-1.494[b] | 1.053[b] | 3.01-10.63[b] | 6.8 lb/ |
| | | | | 0.544-1.528[c] | 1.078[c] | 3.21-10.87[c] | 6.96 lb/ |
| 99 | 176 | [a] | 3 | 0.017-0.025[b] | 0.019[b] | 0.28-0.37[b] | 0.32 |
| | | | | 0.039-0.053[c] | 0.042[c] | 0.64-0.82[c] | 0.72 |
| 99 | 180 | [a] | 5 | 0.042-0.158[b] | 0.11[b] | [a] | [a] |
| 99.6 | 180 | [a] | 5 | 0.067-0.252[b] | 0.131[b] | [a] | [a] |
| [a] | 180 | 0.5 | 3 | 0.0122-0.0988[b] | 0.0312[b] | 0.195-0.997 lb/hr | 0.5 |
| [a] | 125 | [a] | 6 | 0.0065-0.0174 (solid part. and cond. HC) | 0.0115 | 0.04-0.08 | 0.1 |
| | | | | 0.0011-0.0033 (solid particulate) | 0.0092 | | 0.0 |
| [a] | 60-120 | [a] | 7 | 0.005-0.0206 (solid particulate) | 0.0092 | [a] | 0.1 |
| | | | | 0.0333-0.0472 (solid part. and cond. HC) | 0.039 | | 0.56 |
| [a] | 120 | 0.49 | 1 | NA | 0.15[b] | NA | [a] |

TABLE 6. (CONTINUED)

| Emission factors | | | |
|---|---|---|---|
| Range (ton sinter) | Avg. (lb/ton sinter) | Comments | Reference |
| .0[b]/ | 2.0[b]/ | | 49 |
| 2.7[c]/ | 2.34[c]/ | | |
| 10.63[b]/ | 6.87[b]/ lb/ton feed | 4 of the six tests were above 110% isokinetic. | 49 |
| 10.87[c]/ | 6.96[c]/ lb/ton feed | | |
| 0.37[b]/ | 0.32[b]/ | | 50 |
| 0.82[c]/ | 0.72[c]/ | | |
| | [a]/ | | 51 |
| | [a]/ | | 51 |
| 5–0.997 lb/hr | 0.565 lb/hr | Test on FSP pilot unit. | 52 |
| –0.08 | 0.16 | Test on Mikropul pilot wet ESP. Sample not analyzed by EPA Method 5. | 53 |
| | 0.03 | | |
| | 0.13 | Test on pilot gravel bed filter. Sample not analyzed by EPA Method 5 since drying filter and evaporating impinger water drives off condensible hydrocarbons. | 54 |
| | 0.56 | | |
| | [a]/ | | 55 |

| Average emission factor (lb/ton sinter) | Emission factor reliability | Source | Company/ location | Test date | Process production rate | Gas flow rate (dscfm) |
|---|---|---|---|---|---|---|
| a/ | a/ | Controlled emissions from windboxes | Jones & Laughlin Steel Alquippa, PA | 5/75 | a/ | 207,400 |
| 0.185b/ lb/ton feed | B | Controlled emissions from windboxes | Facility C | 2/76 | 184 tons feed/hr | 351,900 |
| a/ | a/ | Controlled emissions from discharge hood, breakers, hot fines bin, two transfer points and vibrating feeder to cooler | Facility C | 7/75 | a/ | 118,500 |
| 6.86b/ lb/ton feed<br>6.86c/ lb/ton feed | B | Uncontrolled emissions from windboxes | Facility F | 6/75 | 329 tons feed/hr | 247,500 |
| 2.0b/ lb/ton feed<br>2.2c/ lb/ton feed | B<br>B | Uncontrolled emissions from windboxes | Facility G | 5/75 | 257 tons feed/hr | 179,000 |
| 0.13b/ lb/ton feed<br>0.19c/ lb/ton feed | B<br>B | Controlled emissions fron windboxes | Facility G | 5/75 | 257 tons feed/hr | 199,000 |
| 0.093b/ | B | Controlled emissions from windboxes | Facility R | 4/76 | 473 tons sinter/hr | 272,200 |
| 0.17b/<br>0.21c/ | B<br>B | Controlled emissions from windboxes | Facility S | a/ | 55 tons sinter/hr | 49,600 |
| 0.956b/ 1.18c/ | A | Controlled emissions from windboxes for east sinter strand | Geneva Works, USS | 6/7-9/78 | 61 tons sinter/hr | 192,000 |
| 0.934b/ 1.19c/ | A | Controlled emissions from windboxes for west sinter strand | Geneva Works, USS | 6/7-9/78 | 58 tons sinter/hr | 181,000 |
| 0.59b/ 0.604c/ | A | Controlled emissions from discharge ends of east and west sinter strand | Geneva Works, USS | 6/7-9/78 | 119 tons sinter/hr | 41,200 |

a/ Reference provides insufficient data or corroboration of data.
b/ Based on particulate collected in the front half of sampling train.
c/ Based on particulate collected in the front and back halves of the sampling train.
d/ Unclear whether value is based on particulate collected in front half of sampling or in front and back halves combin
e/ AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

| | Test methodology | | | | | |
|---|---|---|---|---|---|---|
| Gas temp (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic | Sampling time per run (min) | Gas flow r (dscf |
| 310 | Standard EPA sampling train | West breeching 15 ft downstream of fan outlet and after mechanical collectors | EPA Method 5 | a/ | 120 | 0.47 |
| 229 | a/ | After baghouse | Modified EPA Method 5 | a/ | 75 | a/ |
| 169 | a/ | After baghouse | Modified EPA Method 5 | a/ | a/ | a/ |
| 194 | a/ | Cyclone inlet | Modified EPA Method 5 | a/ | 107 | a/ |
| 272 | a/ | Scrubber inlet | Modified EPA Method 5 | a/ | 180 | a/ |
| 149 | a/ | Scrubber outlet | Modified EPA Method 5 | a/ | 175 | a/ |
| 125 | a/ | Scrubber outlet | Modified EPA Method 5 | a/ | a/ | a/ |
| 105 | a/ | Wet ESP outlet | Modified EPA Method 5 | a/ | a/ | a/ |
| 103 | EPA Method 5 train | In north orifice scrubber outlet stack | EPA Method 5 at 48 points | 98.4-100.9 | 120-144 | 0.49- |
| 105 | EPA Method 5 train | In south orifice scrubber outlet stack | EPA Method 5 at 32 points | 98.9-102.4 | 112-128 | 0.54- |
| 104 | EPA Method 5 train | In orifice scrubber outlet stack | EPA Method 5 at 48 points | 95.7-102.2 | 120-144 | 0.46- |

mbined.

| Gas flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Average (gr/dscf) | Emission factors Range (lb/ton sinter) | Emission factors Average (lb/ton sinter) | Comments |
|---|---|---|---|---|---|---|
| 0.47 | 1 | NA | 0.19[b]/ | NA | [a]/ | |
| [a]/ | 3 | 0.0085-0.0132[b]/ | 0.0113[b]/ | 0.13-0.21[b]/ lb/ton feed | 0.185[b]/ lb/ton feed | Method 5 analytical p include chloroform-et pinger fraction. |
| [a]/ | 3 | 0.004-0.0051[b]/ | 0.0047[b]/ | [a]/ | [a]/ | Same as above |
| [a]/ | 3 | 0.94-1.16[b]/ | 1.05[b]/ | 5.86-7.37[b]/ lb/ton feed | 6.86[b]/ lb/ton feed | Same as above |
| | | 0.94-1.16[c]/ | 1.05[c]/ | 5.9-7.4[c]/ lb/ton feed | 6.86[c]/ lb/ton feed | |
| [a]/ | 4 | 0.323-0.362[b]/ | 0.338[b]/ | 1.9-2.2[b]/ lb/ton feed | 2.0[b]/ lb/ton feed | Same as above |
| | | 0.349-0.392[c]/ | 0.369[c]/ | 2.0-2.4[c]/ lb/ton feed | 2.2[c]/ lb/ton feed | |
| [a]/ | 4 | 0.017-0.025[b]/ | 0.019[b]/ | 0.11-0.16[b]/ lb/ton feed | 0.13[b]/ lb/ton feed | Same as above |
| | | 0.023-0.033[c]/ | 0.027[c]/ | 0.15-0.21[c]/ lb/ton feed | 0.19[c]/ lb/ton feed | |
| [a]/ | 3 | 0.019-0.022[b]/ | 0.[illegible]198[b]/ | [a]/ | 0.093[b]/ | |
| [a]/ | 38 | 0.003-0.022[b]/ | 0.01[b]/ | [a]/ | 0.17[b]/ | |
| | | 0.003-0.017[c]/ | 0.012[c]/ | [a]/ | 0.21[c]/ | |
| 0.49-0.57 | 3 | 0.0273-0.0437[b]/ | 0.0359[b]/ | 0.812-1.1[b]/ | 0.956[b]/ | |
| | | 0.0334-0.0513[c]/ | 0.0442[c]/ | 0.993-1.291[c]/ | 1.18[c]/ | |
| 0.54-0.57 | 3 | 0.0265-0.0439[b]/ | 0.0354[b]/ | 0.72-1.13[b]/ | 0.934[b]/ | |
| | | 0.0342-0.0553[c]/ | 0.0451[c]/ | 0.93-1.423[c]/ | 1.19[c]/ | |
| 0.46-0.49 | 3 | 0.0941-0.2727[b]/ | 0.2013[b]/ | 0.286-0.782[b]/ | 0.59[b]/ | |
| | | 0.0963-0.282[c]/ | 0.206[c]/ | 0.293-0.809[c]/ | 0.604[c]/ | |

TABLE 6. (CONCLUDED)

| Test results | | | | |
|---|---|---|---|---|
| Emission factors | | | | |
| Range (lb/ton sinter) | Average (lb/ton sinter) | Comments | Reference |
| NA | a/ | | 55 |
| 0.13-0.21b/ lb/ton feed | 0.185b/ lb/ton feed | Method 5 analytical procedures were modified to include chloroform-ether extractions of the impinger fraction. | 56 |
| a/ | a/ | Same as above | 56 |
| 5.86-7.37b/ lb/ton feed<br>5.9-7.4c/ lb/ton feed | 6.86b/ lb/ton feed<br>6.86c/ lb/ton feed | Same as above | 56 |
| 1.9-2.2b/ lb/ton feed<br>2.0-2.4c/ lb/ton feed | 2.0b/ lb/ton feed<br>2.2c/ lb/ton feed | Same as above | 56 |
| 0.11-0.16b/ lb/ton feed<br>0.15-0.21c/ lb/ton feed | 0.13b/ lb/ton feed<br>0.19c/ lb/ton feed | Same as above | 56 |
| a/ | 0.093b/ | | 56 |
| a/<br>a/ | 0.17b/<br>0.21c/ | | 56 |
| 0.812-1.1b/<br>0.993-1.291c/ | 0.956b/<br>1.18c/ | | 138 |
| 0.72-1.13b/<br>0.93-1.423c/ | 0.934b/<br>1.19c/ | | 138 |
| 0.286-0.782b/<br>0.293-0.809c/ | 0.59b/<br>0.604c/ | | 138 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 30 lb/ton of input | D | Uncontrolled melting and refining | Company B (AISI data) | a/ | a/ |
| 37 | B | Uncontrolled melting and refining | Company H (AISI data) | 8/29-30/72 | 80 tons of steel per hour |
| 0.11b/ lb/ton of input | A | Controlled melting and refining emissions collected from 4 heats | Company B (AISI data) | 12/19/74 | 290.9 tons of input to furnace per hour |
| 0.09b/<br>0.11c/ | Ce/<br>C | Controlled melting and refining emissions collected from 4 heats | Company B (AISI data) | 12/8-10/71 | a/ |
| 0.21 reported<br>0.15 avg | Ce/<br>B | Controlled melting and refining emissions | Company H (AISI data) | 9/9-10/75 | 80 tons of steel per hour |
| 0.033 | B | Controlled melting and refining emissions | Company A (AISI data) | a/ | 216-230 tons of steel per heat |
| 0.015d/ | Ce/ | Controlled melting and refining emissions | Company A (AISI data) | 11/6-7/74 | 200 tons of steel per hour |
| 0.007 | C | Controlled melting and refining emissions | Company A (AISI data) | 11/16-18/71 | 200 tons of steel per hour |
| 0.105b/ | Ae/ | Controlled melting and refining emissions | Company J (AISI data) | 10/20-22/75 | 170 tons of steel per hour. (42 min avg cycle time) |

| Process conditions | | | Test methodology | | | | |
|---|---|---|---|---|---|---|---|
| Gas flow rate (dscfm) | Gas temp. (°F) | Gas velocity (fpm) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic | Sampli per (m |
| a/ | a/ | a/ | a/ | a/ | a/ | a/ | a/ |
| 159,000 scfm | 380-440 | a/ | ASTM sampling train assembled as components | In 8.5 ft Ø duct before scrubber | ASTM D2928 | a/ | Approx to 30 |
| 269,000 | 245 | 3,564 avg | Lear-Siegler PM100 manual stack sampler | In 18 ft Ø stack following ESP | EPA Method 5 | 106 | 2.3 h 4 hr tion |
| 214,000-224,900 | a/ | a/ | RAC 2343 Staksamplr | In 17 ft Ø stack following venturi scrubber | EPA Method 5 | 81.1-93.3 | 120 |
| a/ | a/ | a/ | a/ | In 8.5 ft Ø duct after scrubber | EPA Method 5 | a/ | a/ |
| 245,000-262-500 | 82-122 | a/ | ASME sampling train | In stack after quencher and scrubber | ASME PTC 27 only during blowing | a/ | 69 |
| 67,900-69,200 | 140-155 | 2,660 | Unspecified but EPA approved | In 6.5 ft Ø stack | EPA Method 5 | 100-102 | 59-7 |
| 56,600-62,400 | a/ | a/ | a/ | a/ | a/ | 101-113 | a/ |
| 227,000-258,000 | 202-207 | 3,100-3,600 | RAC Staksamplr | In 12 ft Ø stack after dry ESP | EPA Method 5 | 100-108 | 140 |

| ampling time per run (min) | Sampling flow rate (dscfm) | No. of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Avg. (gr/dscf) | Emission factors Range (lb/ton steel) | Emission factors Avg. (lb/ton ste |
|---|---|---|---|---|---|---|
| /[a] | [a] | [a] | [a] | [a] | [a] | 30 lb/ton of input |
| pprox. 20 min o 30 min | [a] | 2 - Silicon steel<br>3 - Alloy steel | 2.83-5.57 | 3.28 for silicon steel 4.96 for alloy steel | 22-50 | 37 |
| 2.3 hr during 4 hr of production | 0.53 | 1 | None | 0.02[b] | None | 0.11[b] lb/t of input |
| 120 | [a] | 3 | 0.0199-0.0353[b]<br>0.0281-0.0424[c] | 0.0293[b]<br>0.0369[c] | 0.0705-0.106[b]<br>0.0998-0.127[c] | 0.09[b]<br>0.11[c] |
| [a] | [a] | 7 | [a] | [a] | 0.07-0.28 | 0.15 |
| 69 | [a] | 3 | 0.004-0.02 | 0.011 | 0.012-0.059 | 0.033 |
| 59-75 | [a] | 3 | 0.013-0.015[d] | 0.014[d] | 0.0138-0.0163[d] | 0.015[d] |
| [a] | [a] | 3 | 0.005-0.014 | 0.008 | 0.004-0.0089 | 0.007 |
| 140 | 1.06-1.09 acfm | 3 | 0.012-0.013[b] | 0.012 | 0.0926-0.115 | 0.105 |

TABLE 7. SUMMARY OF EMISSION FACTORS FOR BASIC OXYGEN FURNACES

| t results | | | | |
|---|---|---|---|---|
| s | Emission factors | | | |
| f) | Range (lb/ton steel) | Avg. (lb/ton steel) | Comments | References |
| | a/ | 30 lb/ton of input | Estimate; open hood | 57 |
| or<br>n<br>4.96<br>lloy | 22-50 | 37 | Sampling during blowing; open hood | 58,59 |
| / | None | 0.11b/ lb/ton of input | Open hood | 60 |
| 3b/ | 0.0705-0.106b/ | 0.09b/ | In two of the 3 tests, some particulates passed around filter and passed into impingers; open hood | 57 |
| 9c/ | 0.0998-0.127c/ | 0.11c/ | | |
| | 0.07-0.28 | 0.15 | Scrubber operated between 50 and 60 in. $H_2O$. | 58 |
| | 0.012-0.059 | 0.033 | Sampled during blowing of 4 heats; Scrubber operated between 65 and 76 in. $H_2O$; open hood. | 61 |
| d/ | 0.0138-0.0163d/ | 0.015d/ | After unknown gas cleaning system; Closed hood; sampled during blowing of 4-5 heats per run. | 62,143 |
| | 0.004-0.0089 | 0.007 | Same as above. | 63,143 |
| | 0.0926-0.115 | 0.105 | Sampled during blowing of consecutive heats; open hood | 64 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 0.269[c] | A | Controlled melting and refining emissions | Bethlehem Steel, Bethlehem, PA | 1/72 | 274 tons of per heat |
| 0.21[b] | A | | | | 344 tons of per hour |
| 0.083[c] | C | Controlled melting and refining emissions | Alan Wood Steel, Conshohocken, PA | 11/71 | 146 tons of per heat |
| 0.052[b] | C | | | | 160 tons of per hour |
| 0.0047[c] | A | Controlled melting and refining emissions | U.S. Steel, Lorain, Ohio | 1/72 | 230 tons of per heat |
| 0.0028[b] | A | | | | 276 tons of per hour |
| 0.0079[c] | A | Controlled melting and refining emissions | U.S. Steel, Lorain, Ohio | 11/71 | 230 tons of per heat |
| 0.0044[b] | A | | | | 276 tons of per hour |
| [a] | B | Controlled melting and refining emissions | Inland Steel, E. Chicago, Illinois | 4/75 | 257 tons of per heat |
| [a] | B | Controlled melting and refining emissions | Inland Steel, E. Chicago, IL | 5/75 | 257 tons of per heat |
| [a] | C | Controlled melting and refining emissions | Kaiser Steel, Fontana, Calif. | 7/72 | [a] |

| Process conditions | | | | Test me | | | |
|---|---|---|---|---|---|---|---|
| ess uction te | Gas flow rate (dscfm) | Gas temp. (°F) | Gas velocity (fpm) | Type of sampling device | Location of sampling device | Sampling methodology | Pe isol |
| ns of steel eat ns of steel ur | 493500 | 200 | 2,955 | RAC Model 2343 Staksamplr modified with EPA approval | In 18 ft Ø stack after ESP | Modified EPA Method 5 | 10 |
| ons of steel eat ons of steel our | 211900 | 240 | 1,555 | RAC Model 2343 Staksamplr Modified | 190 ft up in 16.5 ft Ø stack after ESP | EPA Method 5 | 11 (1 11 |
| ons of steel eat ons of steel our | 57650 | 126 | 2,597 | RAC Model 2343 Staksamplr Modified | After cyclone and venturi scrubber. | EPA Method 5 | 10 |
| ons of steel eat ons of steel our | 58770 | 120 | 2,620 | RAC Model 2343 Staksamplr Modified | After cyclone and venturi scrubber. | EPA Method 5 | 1 |
| ons of input eat | 50580 | 123.2 | 2,160 | Model No. AP-5000 Modular Stack-o-Lator | a/ | EPA Method 5 | a |
| ons of input eat | 54250 | 139.8 | 2,382 | Model No. AP-5000 Modular Stack-o-Lator | a/ | EPA Method 5 | a |
| | 190900 | 340 | a/ | 47 mm filter attached to front of probe followed by condensate trap | Precipitator stacks | a/ | |

| Test methodology | | | | Test results | | |
|---|---|---|---|---|---|---|
| | | | | Measured concentrations | | Emiss |
| Percent isokinetic | Sampling time per run (min) | Sampling flow rate (dscfm) | No. of runs performed | Range (gr/dscf) | Avg. (gr/dscf) | Range (lb/ton |
| 106.5 | 120 | 0.72 | 3 | 0.0231 - 0.0516[c]/ | 0.0347[c]/ | 0.161-0.4 |
| | | | | 0.0156 - 0.0451[b]/ | 0.027[b]/ | 0.109-0.3 |
| 116.2 (113.7 - 119.2) | 94 | 0.42 | 3 | 0.00831 - 0.0138[c]/ | 0.0106[c]/ | 0.0631-0. |
| | | | | 0.00499 - 0.00939[b]/ | 0.0067[b]/ | 0.037-0.0 |
| 103.4 | 161 | 0.72 | 3 | 0.00375 - 0.00637[c]/ | 0.0049[c]/ | 0.00335-0 |
| | | | | 0.00164 - 0.00503[b]/ | 0.0029[b]/ | 0.00147-0 |
| 106.4 | 160 | 0.76 | 3 | 0.00466 - 0.0145[c]/ | 0.0081[c]/ | 0.00515-0 |
| | | | | 0.00222 - 0.007[b]/ | 0.0036[b]/ | 0.00202-0 |
| [a]/ | [a]/ | [a]/ | 6 | 0.004 - 0.006[b]/ | 0.005[b]/ | [a]/ |
| [a]/ | [a]/ | [a]/ | 6 | 0.007 - 0.027[c]/ | 0.014[c]/ | [a]/ |
| | | | | 0.006 - 0.011[b]/ | 0.008[b]/ | |
| [a]/ | 15-20 | [a]/ | 2 | [a]/ | 0.01134 gr/scf | [a]/ |

TABLE 7. (CONTINUED)

| Test results | | | | |
|---|---|---|---|---|
| ncentrations | Emission factors | | | |
| Avg. (gr/dscf) | Range (lb/ton steel) | Avg. (lb/ton steel) | Comments | Reference |
| 0.0347[c]/ | 0.161-0.402[c]/ | 0.269[c]/ | Sampling from end of charge to beginning of tap; covered 4 heats; open hood. | 65 |
| 0.027[b]/ | 0.109-0.352[b]/ | 0.21[b]/ | | |
| 0.0106[c]/ | 0.0631-0.107[c]/ | 0.083[c]/ | Sampling from beginning of scrap preheat to beginning of tap; covered 4 heats/run; open hood. | 66 |
| 0.0067[b]/ | 0.037-0.073[b]/ | 0.052[b]/ | | |
| 0.0049[c]/ | 0.00335-0.00612[c]/ | 0.0047[c]/ | Sampling from beginning of blow to beginning of tap; 6 heats covered; closed hood. | 67 |
| 0.0029[b]/ | 0.00147-0.00484[b]/ | 0.0028[b]/ | | |
| 0.0081[c]/ | 0.00515-0.0135[c]/ | 0.0079[c]/ | Sampling from end of charge to beginning of tap; 6 heats covered; newly installed scrubbers; closed hood. | 68 |
| 0.0036[b]/ | 0.00202-0.00827[b]/ | 0.0044[b]/ | | |
| 0.005[b]/ | [a]/ | [a]/ | Sampling from beginning of blow to beginning of tap; 2 heats/run; closed hood. | 69 |
| 0.014[c]/ | [a]/ | [a]/ | Sampling from beginning of preheat to beginning of tap; 2 heats/run; closed hood. | 69 |
| 0.008[b]/ | | | | |
| 0.01134 gr/scf | [a]/ | [a]/ | Sampling during one blow period/run; open hood. | 70 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 0.0158[c]/ | A | Controlled melting and refining emissions | Armco Steel, Middletown, Ohio | 10/71 | 200 tons steel per heat |
| 0.0132[b]/ | A | | | | |
| 0.114[c]/ | C | Controlled melting and refining emissions | National Steel, Weirton, WVA | 12/71 | 340 tons steel per heat |
| 0.106[b]/ | C | | | | |
| 0.0556[b]/ - primary hood | A | Controlled melting, refining, charging and tapping emissions from a Q-BOP | Republic Steel, Chicago, IL | 8/77 | 247 tons input per |
| 0.0504[b]/ - secondary hood | A | | | | 247 tons input per |
| 0.0092[d]/ lb per ton of input | C | Controlled melting refining, charging and tapping emissions from a Q-BOP | U.S. Steel, Fairfield, AL | 11/74 | 227 tons per heat 332 tons per hr |
| a/ | a/ | Controlled melting refining, charging and tapping emissions from a Q-BOP | U.S. Steel, Fairfield, AL | 10/78 | a/ |
| a/ | a/ | Controlled melting, refining, charging and tapping emissions from a Q-BOP | U.S. Steel Fairfield, AL | 10/78 | a/ |
| a/ | a/ | Controlled melting and refining emissions | Bethlehem Steel Burns Harbor, IL | 1974 | 300 tons |
| a/ | a/ | Controlled melting and refining emissions | Kaiser Steel, Fontana, Calif. | 1972 | 120 tons |
| a/ | a/ | Controlled melting and refining emissions | Interlake Steel, Chicago, IL | 1975 | 80 tons |

| Process conditions | | | | Test methodology | | | |
|---|---|---|---|---|---|---|---|
| | Gas flow rate (dscfm) | Gas temp. (°F) | Gas velocity (fpm) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic |
| f | 39,300 | 148 | 1,835 | RAC Model 2343 Staksamplr conforming to Method 5 | BOF Stack No. 15, after venturi scrubbers | EPA Method 5 | 103 |
| f | 219,000 | 138 | 1,304 | RAC Model 2343 Staksamplr Modified with EPA approval | In stack after venturi scrubber | EPA Method 5 | 87 (only one test between 90 and 110) |
| f heat f hr | 90,000- primary hood 180,000- secondary hood | 140- primary hood 120- secondary hood stack gas | a/ | a/ | In stack after venturi scrubber | EPA Method 5 with approved modifications | 98 |
| f input | 68,600 | 145 | a/ | a/ | In stack after gravity collector, quencher, and scrubber | a/ | 101 |
| f input | 76,300 | 163 | 3,352 | Standard EPA Method 5 train | After scrubber controlling primary hood catch | EPA Method 5 | 98.7 |
| | 92,700 | 158 | 3,752 | Standard EPA Method 5 train | After scrubber controlling primary hood catch | EPA Method 5 | 105 |
| per heat | a/ | a/ | a/ | a/ | After venturi scrubber | EPA Method 5 | a/ |
| per heat | a/ | a/ | a/ | a/ | After ESP | a/ | a/ |
| er heat | a/ | a/ | a/ | a/ | After ESP | a/ | a/ |

TABLE 7. (continued)

| Test results | | | | |
|---|---|---|---|---|
| ions | Emission factors | | | |
| cf) | Range (lb/ton steel) | Avg. (lb/ton steel) | Comments | Reference |
| 35[c]/ 25[b]/ | 0.0158[c]/ 0.0115-0.0141[b]/ | 0.0158[c]/ 0.0132[b]/ | Sampling from end of charge to beginning of tap; 6 heats per test; closed hood. | 71 |
| 59[c]/ 53[b]/ | 0.0998-0.127[c]/ 0.106[b]/ | 0.1143[c]/ 0.106[b]/ | Sampling from end of charge to beginning of tap; 4 heats per run; open hood. | 72 |
| 23[b]/ ary hood) 99[b]/ hood) | 0.0548-0.0564[b]/ (primary hood) 0.037-0.0638[b]/ (secondary hood) | 0.0556[b]/ (primary hood) 0.0504[b]/ (second. hood) | 6 heats per run; secondary hood collects charging and tapping emissions; primary hood collects blowing emissions; closed hood. | 73 |
| d/ | a/ | 0.0092[d]/ | Closed hood; pressure drop across scrubber is 57 in. $H_2O$; sampled during oxygen blow. | 74 |
| 180[b]/ | a/ | a/ | Sampled during oxygen blow; closed hood. | 75 |
| 006[b]/ | a/ | a/ | Sampled from beginning of blow to beginning of tapping (therefore, includes turndown); closed hood. | 75 |
| b/ | a/ | a/ | Open hood; pressure drop across scrubber is 55 in. $H_2O$. | 76 |
| b/ | a/ | a/ | Open hood. | 76 |
| b/ | a/ | a/ | Open hood. | 76 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 24.2[b] | A | Uncontrolled melting and refining emissions. | CF&I Steel, Pueblo, CO | 4/10-17/78 | 120 tons/he |
| 0.0614[b] | A | Controlled melting and refining emissions. | CF&I Steel, Pueblo, CO | 4/10-17/78 | 120 tons/he |
| 0.137[d] lb/ton of input | C[e] | Controlled melting and refining emission | Company J (AISI data) | 2/11,12, 17/76 | 305 tons cha per hour 45 min. avg cycle time |
| 0.162[d] lb/ton of input | C[e] | Controlled melting and refining emission | Company J (AISI data) | 12/8-10/75 | a |
| 0.291 | B[e] | Tapping | Company D (AISI data) | 4/28-29/75 | 196-216 tons steel per he |
| 0.142 lb/ton of hot metal charged | B[e] | Charging | Company D (AISI data) | 4/28-29/75 | 147-182 tons hot metal cha per heat |
| 0.056 lb/ton of metal poured | B[e] | Hot metal transfer | Company D (AISI data) | 5/1/75 | 160-184 tons hot metal pou per heat |
| 0.28 | C | Monitor emissions | Company A (AISI data) | a | a |
| 0.34-Emissions escaping monitor during 1 hr time<br>0.16-captured charging emissions<br>0.5-captured charging emissions and uncaptured monitor emissions | B[e] | Uncontrolled monitor emissions | Company A (AISI data) | Feb. and March 1975 | 6,400 tons of steel per day |

| | Process conditions | | | Test methodology | | |
|---|---|---|---|---|---|---|
| | Gas flow rate (dscfm) | Gas temp. (°F) | Gas velocity (fpm) | Type of sampling device | Location of sampling device | Sampling methodology |
| at | 90,600-104,400 | 458-515 | 4,780-5,550 | In-stack alundum thimble | In duct before ESP | ASME PTC 27 |
| at | 151,500-169,900 | 247-289 | 4,040-4,410 | Method 5 train | In stack after ESP | EPA Method 5 (undetermined No. of points) |
| rged | 383,000-399,000 | 250-282 | 5,900-6,400 | a/ | In 12 ft Ø stack after dry ESP | EPA Method 5 |
| | 268,000-287,000 | 247-269 | 4,400-5,000 | a/ | After dry ESP | EPA Method 5 |
| of at | a/ | a/ | a/ | a/ | a/ | In-stack filter; tapping emissions captured by primary hood. |
| of rged | a/ | a/ | a/ | a/ | a/ | In-stack filter; charging emissions captured by primary hood. |
| of red | a/ | a/ | a/ | a/ | a/ | In-stack filter; emissions captured by reladling station hood. |
| | a/ | a/ | a/ | Hi-Vols and hot wire anemometers | In roof monitor | Divided monitor into 12 equal area sections and sampled in each section. |
| | 30,700-104,000 acfm (through an opening within a zone) | a/ | 169-378 fpm (through openings) | 3 Gelman Hurricane air samplers and Datametrics air flow multimeters (hot-wire anemometers) | In front of openings in room monitor and side of building | Divided building into 8 zones. Each zone has 3 openings: an east and west monitor opening and an opening in the east side of the building at at intermediate level. Sample all 3 openings simultaneously. Repeated process for each zone. |

| ethodology | | | | | Test results | | |
|---|---|---|---|---|---|---|---|
| | | | | | Measured concentrations | | Emission f |
| | Percent isokinetic | Sampling time per run (min) | Sampling flow rate (dscfm) | No. of runs performed | Range (gr/dscf) | Avg. (gr/dscf) | Range (lb/ton steel) |
| | 90-109 | 72-79 | 0.3 | 5 | 7.26-9.32[b] | 8.1[b] | 21.4-27.7[b] |
| rmined | 92-100 | 75-83 | 0.6 | 5 | 0.00935-0.022[b] | 0.0125[b] | 0.0426-0.112 |
| | 85-94 | 144 | [a] | 3 | 0.0115-0.018[d] | 0.0165[d] | 0.12-0.15[d] |
| | [a] | [a] | [a] | 5 | 0.014-0.029[d] | 0.019[d] | 0.14-0.21[d] lb/ton input |
| pping y | [a] | [a] | [a] | 15 | 0.0218-0.387 gr/acf | 0.0935 gr/acf | 0.051-0.891 |
| rging primary | [a] | [a] | [a] | 15 | 0.0675-0.526 gr/acf | 0.210 gr/acf | 0.025-0.369 lb/ton hot metal charged |
| sions station | [a] | [a] | [a] | 8 | 0.0690-0.237 gr/acf | 0.13 gr/acf | 0.029-0.098 lb/ton hot metal poured |
| 12 equal pled in | [a] | [a] | [a] | 1 in each of 12 sections. | [a] | [a] | [a] |
| 8 zones. ngs: tor in the ding at Sampled aneously. each | [a] | 1 hr/zone | 33-57 acfm | 3 simultaneous runs/zone and 8 zones/test and 3 tests. | 0.0026-0.0389 gr/acf | - | 0.28-0.44 |

TABLE 7 (continued)

| Test results | | | | |
|---|---|---|---|---|
| ations | Emission factors | | | |
| vg. /dscf) | Range (lb/ton steel) | Avg. (lb/ton steel) | Comments | Reference |
| .1b/ | 21.4-27.7b/ | 24.2b/ | Sampled during blowing and reblowing; open hood. | 137 |
| .0125b/ | 0.0426-0.1122b/ | 0.0614b/ | Sampled during blowing and reblowing; open hood. | 137 |
| .0165d/ | 0.12-0.15d/ | 0.137d/ lb/ton input | Sampled during oxygen blow of consecutive heats. Open Hood | 78 |
| .019d/ | 0.14-0.21d/ lb/ton input | 0.162d/ lb/ton input | Open hood | 79 |
| .0935 gr/acf | 0.051-0.891 | 0.291 | Value represents uncontrolled emissions factor calculated assuming 93% avg capture efficiency. | 50 |
| .210 gr/acf | 0.025-0.369 lb/ton hot metal charged | 0.142 lb/ton hot metal charged | Value represents uncontrolled emission factor calculated assuming 78% avg capture efficiency. | 81 |
| .13 gr/acf | 0.029-0.098 lb/ton hot metal poured | 0.056 lb/ton hot metal poured | Assumed 100% capture efficiency. | 22 |
| a/ | a/ | a/ | | 33 |
| - | 0.28-0.44 | 0.34 | This BOF shop had a secondary hood capturing charging emissions. 0.16 lb/ton was captured in the hood. | 84 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test data | Process production rate |
|---|---|---|---|---|---|
| 0.3 | C[e] | Monitor emissions | Company A (AISI data) | 7/1-2/75 | 12,000 tons steel per d |
| 0.147 | C | Monitor emissions | Interlake, Inc. Riverdale, IL | [a] | 100 tons of steel per h |
| [a] | [a] | Uncontrolled monitor emissions | CF&I Steel Pueblo, Col. | 12/2-4/75 | 120 tons/h |
| [a] | [a] | Uncontrolled monitor emissions | CF&I Steel Pueblo, Col. | 12/2-4/75 | 120 tons/h |
| [a] | [a] | Uncontrolled monitor emissions | CF&I Steel Pueblo,Col. | 12/2-4/75 | 120 tons/h |
| [a] | [a] | Uncontrolled monitor emissions | CF&I Steel Pueblo,Col. | 12/2-4/75 | 120 tons/h |
| 0.19[b]/ lb/ton metal<br>0.192[c]/ lb/ton hot metal | A | Hot metal transfer | Wisconsin Steel Chicago, IL | April, May 1978 | 29.1-90.4 of hot met of pourin |
| 0.6[b]/ lb/ton hot metal<br>0.66[c]/ lb/ton hot metal | A | Charging | Republic Steel Chicago, IL | March, May 1978 | 49.5-91.6 of hot me of chargi |
| 0.92[b]/<br>0.96[c]/ | A | Tapping | Republic Steel Chicago, IL | March 1978 | 37.6-48 t steel tap |
| 0.3-0.4 | D | Charging | [a] | [a] | [a] |
| 0.15-0.2 | D | Tapping | [a] | [a] | [a] |

[a] Reference provides insufficient data or corroboration of data.
[b] Based on particulate collected in front half of sampling train.
[c] Based on particulate collected in front and back halves of sampling train.
[d] Unclear whether value is based on particulate collected in front half of sampling train or in
[e] AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

| Process conditions | | | | Test met | | |
|---|---|---|---|---|---|---|
| ess ction te | Gas flow rate (dscfm) | Gas temp. (°F) | Gas velocity (fpm) | Type of sampling device | Location of sampling device | Sampling methodology |
| 0 tons of per day | 152,000-33,150 330,150 acfm (through an opening) | a/ | 380-1,080 fpm (through openings) | 1 Gelman Hurricane air sampler and a flowtronic Model 55B1 hot-wire anemometer | In front of opening in roof monitor | Divided buildin zones. Each zon only one openin |
| ons of per hr | a/ | 300 | a/ | MSA personnel samplers | Grate in roof monitor above operating 80T BOF. | a/ |
| tons/heat | $1.62 \times 10^6$-$2.58 \times 10^6$ scfm | a/ | 488-775 | a/ | Roof monitor openings | High volume sam |
| tons/heat | $2.44 \times 10^6$ scfm | a/ | 729 | a/ | Roof monitor openings | High volume sam |
| tons/heat | $2.24 \times 10^6$ $2.53 \times 10^6$ scfm | a/ | 669-757 | a/ | Roof monitor openings | High volume sam |
| tons/heat | $2.35 \times 10^6$-$2.45 \times 10^6$ scfm | a/ | 721-736 | a/ | Roof monitor openings | High volume sam |
| 1-90.4 tons hot metal/min pouring | 33,000-46,000 | 135-248 | 3,840-4,530 | Method 5 train | In hot metal transfer hood branch duct leading to ESP | EPA Method 5. sampled per te |
| 5-91.6 tons hot metal/min charging | 268,000-463,000 | 168-234 | 4,610-7,600 | Method 5 train | In secondary hood duct leading to wet scrubber; probe located 1.5 dia. downstream of bend in duct | Single point sample |
| 6-48 tons of el tapped/min | 106,000-196,500 | 173-313 | 1,790-3,850 | Method 5 train | Same as above | EPA Method 5. points sampled |
| | a/ | a/ | a/ | a/ | a/ | a/ |
| | a/ | a/ | a/ | a/ | a/ | a/ |

or in fron and back halves combined.
S.

| st methodology | | | | | Test Results | | |
|---|---|---|---|---|---|---|---|
| | | | | | Measured concentrations | | |
| y | Percent isokinetic | Sampling time per run (min) | Sampling flow rate (dscfm) | No. of runs performed | Range (gr/dscf) | Avg. (gr/dscf) | (lb |
| uilding into 9 h zone has pening. | a/ | a/ | a/ | 1 run/zone and 9 zones/ test and 3 tests | 0.02-0.037 gr/acf | 0.008 gr/acf | 0.2 |
| | a/ | a/ | 0.06 acfm | 4 | a/ | 0 0027 gr/acf | a/ |
| e samplers | 95 | a/ | a/ | 3 | 0.019-0.028 | 0.024 | a/ |
| e samplers | 95 | a/ | a/ | 1 | | 0.005 | a/ |
| e samplers | 95 | a/ | a/ | 3 | 0.005-0.012 | 0.009 | a/ |
| e samplers | 95 | a/ | a/ | 2 | 0.005-0.007 | 0.006 | a/ |
| 1 5. 8 points er test. | 91.1-109.7 | 1.3-3.0 | 2.8-5.1 | 8 | 0.0844-9.682b/ | 1.6567b/ | 0. 1b |
| | | | | | 0.1095-9.6994c/ | 1.6769c/ | 0. 1b |
| int | 97.2-107.5 | 2.2-4.3 | 2.8-4.5 | 6 | 0.379-2.359b/ | 0.917b/ | 0. 1b |
| | | | | | 0.4445-2.3902c/ | 1.0118c/ | 0. 1b |
| d 5. 10-12 mpled/test | 92.6-102.5 | 4.7-6.0 | 1.0-2.0 | 3 | 0.3853-3.8973b/ | 1.6558b/ | 0. |
| | | | | | 0.4413-3.9714c/ | 1.7269c/ | 0. |
| | a/ | a/ | a/ | a/ | a/ | a/ | 0 |
| | a/ | a/ | a/ | a/ | a/ | a/ | 0 |

TABLE 7. (CONCLUDED)

| Test Results | | | | |
|---|---|---|---|---|
| ntrations | Emission factors | | | |
| Avg. (gr/dscf) | Range (lb/ton steel) | Avg. (lb/ton steel) | Comments | Reference |
| 0.008 gr/acf | 0.26-0.31 | 0.3 | Open hood | 85 |
| 0 0027 gr/acf | a/ | 0.147 | Made multipoint nonsimultaneous velocity measurements with thermal and vane type anemometers. | 86,87 |
| 0.024 | a/ | a/ | Short term tests from charging initiation to time when building clears. | 88 |
| 0.005 | a/ | a/ | Test ran over cycle marked by the time the building clears after charging. | 88 |
| 0.009 | a/ | a/ | Tests ran over cycle marked by slagging initiation. | 88 |
| 0.006 | a/ | a/ | Tests ran over cycle marked by charge initiation. | 88 |
| / 1.6567b/ | 0.009-0.511b/ lb/ton hot metal | 0.118b/ lb/ton hot metal | Tests ran over 1-2 transfer operations. Avg EF in far left column is adjusted to account for uncaptured emissions. | 133 |
| e/ 1.6769c/ | 0.012-0.512b/ lb/ton hot metal | 0.119c/ lb/ton hot metal | | |
| 0.917b/ | 0.2-1.2b/ lb/ton hot metal | 0.6b/ lb/ton hot metal | Sampling was done at a different point along the traverse for each test so that only the avg of the six tests is representative | 134 |
| e/ 1.0118c/ | 0.23-1.22c/ lb/ton hot metal | 0.66c/ lb/ton hot metal | | |
| b/ 1.6558b/ | 0.15-2.28b/ | 0.92b/ | | 134 |
| c/ 1.7269c/ | 0.18-2.32c/ | 0.96c/ | | |
| a/ | 0.3-0.4 | 0.35 | Estimate | 77 |
| a/ | 0.15-0.2 | 0.17 | Estimate | 77 |

There are also specific charging and tapping EFs listed in Table 7. There are seventeen A-rated EFs, nine B-rated factors, sixteen C-rated factors, three D-rated factors, and nine unrateable tests in Table 7.

Also shown in Table 7, where data were avilable is whether the furnace was top or bottom blown and whether the hood was open or closed. Under the table heading entitled Source, a top blown furnace should be inferred unless the furnace is specifically identified as a Q-BOP. Whether the hood is open or closed is a fact to be found under the table heading entitled Comments.

The exact processes included in the source listed as Melting and Refining in Table 7 are of importance in utilizing the emission factor value given. There are three possible sources: (a) scrap preheat, (b) blowing or refining, and (c) turndown, i.e., the period during which a sample of the heat is taken and analyzed. Where the data were available, what precise processes were tested are listed under the table heading entitled Comments.

## 3.5 ELECTRIC ARC FURNACES

There are several sources of particulate emission in the electric arc furnace steelmaking process. The emission sources are (a) emissions from the melting and refining of the heat itself, often vented through a hole in the furnace roof, (b) charging scrap, (c) dumping slag, and (d) tapping steel.

There are several possible configurations of control systems to capture and remove emissions. Figures 3 and 4 show some of the more common configurations. Configuration 1 in Figure 3 is the building evacuation system; Configuration 2 in Figure 4 is direct shell evacuation (DSE) of melting and refining emissions and canopy hood capture of charging, tapping, and slagging emissions with both venting to a common baghouse. There are several variations on Configuration 2: (a) the roof monitor can be open to release those emissions not captured by the canopy hood or closed, or (b) the canopy hood and the DSE system can be vented to separate control devices rather than a common emission removal device.

In interpreting emission factor data for EAFs, it is important to know which configuration was sampled and where the sample was collected. For example, suppose Configurations 1 and 2 shown in Figures 3 and 4 are both sampled at the baghouse inlet. The value obtained from Configuration 1 would represent all melting, refining, charging, tapping, and slagging emissions which ascended to the building roof while the value obtained from Configuration 2 would represent nearly all the melting and refining emissions but only that portion of the charging, tapping, and slagging emissions which were captured by the canopy hood.

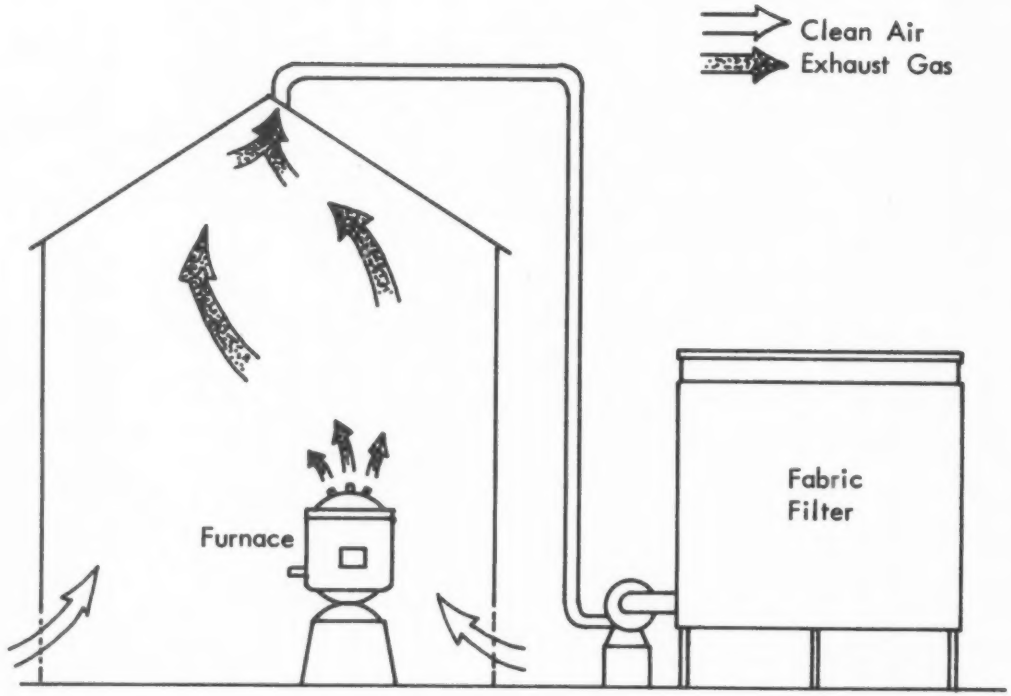


Figure 3. Building evacuation (BE) system closed roof--Configuration 1.

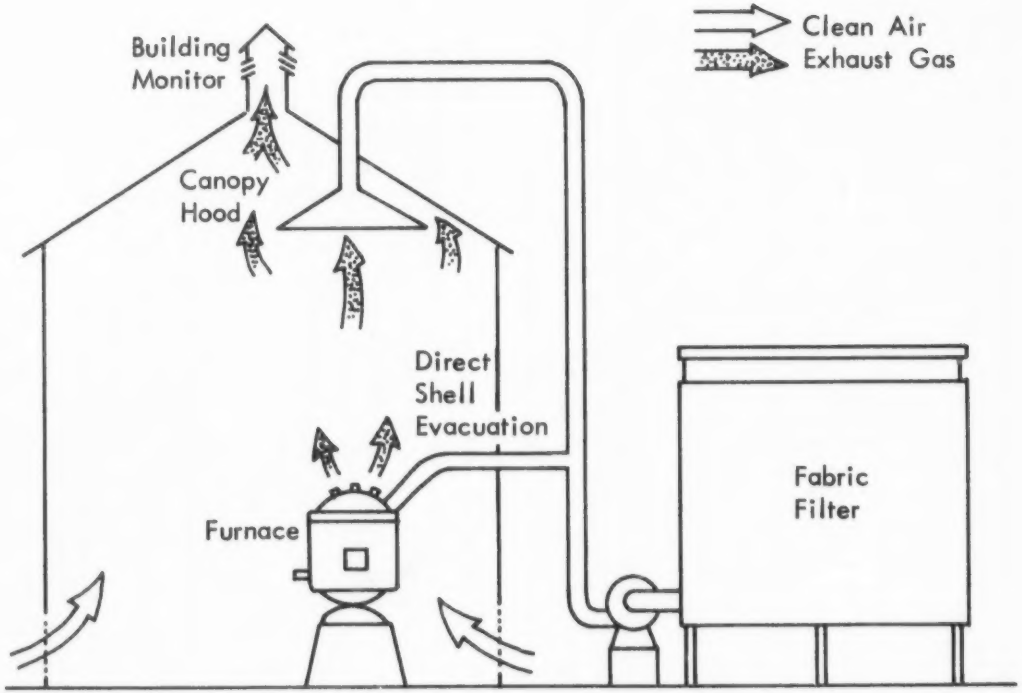


Figure 4. Canopy hood (CH) open roof--Configuration 2.

Table 8 lists EFs for particulate sources in EAF shops. Melting and refining, referred to in Table 8, imply mainly emissions captured by direct shell evacuation through a hole in the furnace roof. Monitor emissions include the portion of charging, tapping, and slagging emissions that escape into the atmosphere. When the secondary controls are not specified for a monitor test, it is difficult to judge the typicalness of or to utilize the results.

Listed in the comments column of Table 8 are two of the important parameters which effect the emission factors: (a) whether the process was to produce carbon or alloy steel (two significantly different processes), and (b) what control device configuration was used.

There are four A-rated EFs in Table 8 and twenty-one C-rated EFs. The dearth of A- and B-rated EFs is due to poor sampling methods or a failure to report the sampling method. The poor sampling methods were often not the fault of the test designer but coupled more with the problems encountered in sampling a pressure baghouse.

## 3.6 OPEN HEARTH FURNACES

There are several sources of particulate emission in the open hearth furnace steelmaking process. The activities generating emissions are (a) transferring hot metal, (b) melting and refining the heat, (c) charging of scrap and/or hot metal, (d) dumping slag, and (e) tapping steel.

Table 9 lists EFs for particulate sources in OHF shops. Monitor emissions refer to the portion of the hot metal transfer, charging, tapping, and slagging emissions that enter the atmosphere through the shop roof monitor. There are only 10 total EFs presently included in the data base. Four of these are A-rated, one is B-rated, and five are C-rated. The main problem is failure to report not only the details of the tests, but the test methodologies themselves.

## 3.7 TEEMING

Only one investigative effort to quantify an emission factor for teeming is available.[133] The emission factors were measured via stack testing in the ductwork leaving a side draft hood which captured emissions from a teeming operation. Emissions were measured simultaneously before and after the baghouse removing the captured emissions.

Tests were performed during the teeming of leaded and unleaded steel. Only the material captured by the hood could be measured via stack tests. The material captured varied from nearly 100% of that emitted to a much lower efficiency (not quantified) when the wind was blowing from directions where building openings occurred.

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate |
|---|---|---|---|---|---|
| 0.3d/(Alloy Steel) | A | Controlled EAF melting, refining, charging, tapping, and slagging emissions. | Babcock and Wilcox Beaver Falls, PA | 10/18-20/72 | 18T steel/hr |
| 0.58e/ | A | | | | |
| 11.3d/ (Alloy Steel) | A | Uncontrolled EAF melting, refining, charging, tapping, and slagging emissions. | Babcock and Wilcox Beaver Falls, PA | 10/18-20/72 | 18T steel/hr |
| 11.7e/ | A | | | | |
| 7.6 | C | Uncontrolled EAF melting and refining emissions. | a/ | a/ | 14.4T input/hr |
| 11.0 | C | Uncontrolled EAF melting and refining emissions. | a/ | a/ | 13.6-23.5T/hr |
| 4.8 | C | Controlled EAF melting and refining emissions. | a/ | a/ | 13.6-22 T input hr |
| 19.5 lb/ingot ton | C | Uncontrolled EAF melting and refining emissions. | Company K (AISI data) | 1/15-24/75 | a/ |
| 28.8 lb/T of input (stainless and alloy) | C | Uncontrolled EAF melting and refining emissions. | Company J (AISI data) | Jan.-April 1976 | 78,000-83,000 T steel/month |
| 17.1 | C | Uncontrolled EAF melting and refining emissions. | Company H (AISI data) | 10/18-25/75 and 6/8/76 | 4,080 T steel tapped over 7- test period. T steel tapped over weekend. |

| Test methodology | | | | | | |
|---|---|---|---|---|---|---|
| Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic | Sampling time (min) | Gas flow rate (dscfm) | Number of runs performed |
| Method 5 EPA train | In short stacks after baghouse | EPA method 5 except probe was not heated | 96-104.7 | 240 | 0.75-0.79 | 9 |
| Method 5 EPA train | In 12 ft Ø duct before baghouse | EPA Method 5 except probe was not heated | 97.4-99.5 | 240 | 0.72-0.79 | 3 |
| a/ | a/ | a/ | a/ | a/ | a/ | 1 |
| a/ | a/ | a/ | a/ | a/ | a/ | 5 |
| a/ | In stack after scrubber | a/ | a/ | a/ | a/ | 2 |
| a/ | a/ | Weighed control device catch and divided by ingot tons produced | a/ | a/ | a/ | 10 |
| a/ | a/ | Weighed control device catchand divided by tons of steel melted | a/ | a/ | a/ | 4 |
| a/ | a/ | Weighed control device catch and divided by tons of steel tapped | a/ | a/ | a/ | 2 |

TABLE 8. SUMMARY OF EMISSION FACTORS

| Test results | | | | |
|---|---|---|---|---|
| Measured concentrations | | Emission factors | | |
| Range (gr/dscf) | Average (gr/dscf) | Range lb/ton steel | Average lb/ton steel | Comments |
| 0.0005–0.0032[d] | 0.0014[c] | 0.11–0.66[d] | 0.3 | Shop has 1/50 T and 1/75 T alloy Steel EAF; control device configuration 1 |
| 0.0014–0.0047[e] | 0.0027[e] | 0.34–0.95[e] | 0.58[e] | |
| 0.0386–0.0605[d] | 0.0518[d] | 8–13.6[d] | 11.3[d] | Shop has 1/50 T and 1/75 T alloy steel EAF; control device configuration 1 |
| 0.0397–0.0618[e] | 0.0537[e] | 8.2–13.9[e] | 11.7[e] | |
| None | 0.5373 | None | 7.6 | 50 T furnace. Unclear whether carbon or alloy steel. |
| [a] | [a] | 6.9–18.6 | 11.0 | 50 and 75 T furnace. Unclear whether carbon or alloy steel. |
| 0.109–0.556 | 0.333 | 2.04–7.65 | 4.8 | 50 and 75 furnace. Scrubber control efficiencies of 37 and 70%. Unclear whether carbon or alloy steel. |
| None | None | 15.1–34.8 lb/ingot ton | 19.5 lb/ingot ton | Carbon steel |
| None | None | 29–34.2 lb/T steel | 31.7 lb/T steel | |
| None | None | 13.4–20.8 | 17.1 | Alloy steel |

TABLE 8. SUMMARY OF EMISSION FACTORS FOR ELECTRIC ARC FURNACES

| Emission factors | | | |
|---|---|---|---|
| Range ton steel | Average lb/ton steel | Comments | Reference |
| 1-0.66[d] | 0.3 | Shop has 1/50 T and 1/75 T alloy | 89 |
| 4-0.95[e] | 0.58[e] | Steel EAF; control device configuration 1 | |
| 3.6[d] | 11.3[d] | Shop has 1/50 T and 1/75 T alloy | 89 |
| -13.9[e] | 11.7[e] | steel EAF; control device configuration 1 | |
| e | 7.6 | 50 T furnace. Unclear whether carbon or alloy steel. | 90 |
| -18.6 | 11.0 | 50 and 75 T furnace. Unclear whether carbon or alloy steel. | 90 |
| 4-7.65 | 4.8 | 50 and 75 furnace. Scrubber control efficiencies of 37 and 70%. Unclear whether carbon or alloy steel. | 90 |
| 1-34.8 ingot | 19.5 lb/ingot ton | Carbon steel | 91,143 |
| 34.2 T steel | 31.7 lb/T steel | | 92 |
| 4-20.8 | 17.1 | Alloy steel | 93,143 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process production rate | Pro |
|---|---|---|---|---|---|---|
| 0.043 | C[b] | Controlled EAF melting and fugitive emissions and uncontrolled, uncaptured monitor emissions. | Company L (AISI data) | 10/9/74 | 33 ton steel/h | |
| 25 | C | Uncontrolled EAF melting and refining emissions. | a/ | a/ | a/ | |
| 16 | C | Uncontrolled EAF melting and refining emissions. | a/ | a/ | a/ | |
| 50 | C | Uncontrolled EAF melting and refining emissions. | Lukens Steel Coatsville, PA | a/ | a/ | |
| 51[c] | C | Uncontrolled EAF melting and refining emissions. | Jones & Laughlin Cleveland, OH | a/ | a/ | |
| 22 | C | Uncontrolled EAF melting and refining emissions. | Bethlehem Steel Seattle, WA | a/ | a/ | |
| 1.2 | C | Charging and tapping emissions. | Bethlehem Steel Seattle, WA | a/ | a/ | |
| 1.7 | C | Charging and tapping emissions. | Bethlehem Steel Steelton, PA | a/ | a/ | |
| 27.5 | C | Uncontrolled EAF melting and refining emissions. | Bethlehem Steel Steelton, PA | a/ | a/ | |
| 43.0 | C | Uncontrolled EAF melting and refining emissions plus all fugitive emissions. | Bethlehem Steel Los Angeles, CA | a/ | a/ | |

| Process conditions | | | Test methodology | | | | |
|---|---|---|---|---|---|---|---|
| ess ction te | Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic | Sa t (e |
| steel/hr | 247,000-256,000 | a/ | Rader pneumatics high volume sampler. | In north exhaust plenum of baghouse. | Single point sampled | 150-204 | 140 |
| | a/ | a/ | a/ | a/ | a/ | a/ | a/ |
| | a/ | a/ | a/ | a/ | a/ | a/ | a/ |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |
| | a/ | a/ | a/ | Test at inlet to ESP | a/ | a/ | a/ |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |
| | a/ | a/ | a/ | a/ | Took measurements in roof monitor | a/ | a/ |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |

| cent inetic | Sampling time (min) | Gas flow rate (dscfm) | Number of runs performed | Test results: Measured concentrations Range (gr/dscf) | Measured concentrations Average (gr/dscf) | Emission factors Range lb/ton steel | Emission factors Average lb/ton steel | Comme |
|---|---|---|---|---|---|---|---|---|
| 204 | 140-245 | 17.3 | 2 | 0.00065-0.00121 | 0.0009 | 0.041-0.045 | 0.043 | Canopy hood furnace. Es of total em capture and lanced carb device conf |
| | a/ | a/ | a/ | a/ | a/ | 20-30 | 25 | Unclear wh alloy steel |
| | a/ | a/ | a/ | a/ | a/ | 3-30 | 16 | Unclear wh alloy steel |
| | a/ | a/ | a/ | None | a/ | a/ | 50 | Carbon ste configurat |
| | a/ | a/ | a/ | a/ | a/ | a/ | 51c/ | Carbon ste device con of DSE vent |
| | a/ | a/ | a/ | None | None | a/ | 22 | Carbon ste device con DSE. Build |
| | a/ | a/ | a/ | None | None | 0.9-1.5 | 1.2 | DSE each v baghouse. |
| | a/ | a/ | a/ | a/ | a/ | a/ | 1.7 | Carbon ste configurat vented to |
| | a/ | a/ | a/ | None | None | a/ | 25-30 | Carbon ste configurat vented to |
| | a/ | a/ | a/ | None | None | a/ | 43 | Carbon ste configurati monitor lo closing th capture fu |

TABLE 8. (continued)

| Test results | | | | | |
|---|---|---|---|---|---|
| d concentrations | Emission factors | | | | |
| Average (gr/dscf) | Range lb/ton steel | Average lb/ton steel | Comments | Reference |
| 0.0009 | 0.041-0.045 | 0.043 | Canopy hood is 70 ft above furnace. Estimated that 25% of total emissions escaped capture and left monitor; $O_2$ lanced carbon steel; control device configuration 2 | 94 |
| a/ | 20-30 | 25 | Unclear whether carbon or alloy steel. | 95 |
| a/ | 3-30 | 16 | Unclear whether carbon or alloy steel. | 96 |
| a/ | a/ | 50 | Carbon steel; control device configuration 2 | 97 |
| a/ | a/ | 51c/ | Carbon steel; modified control device configuration consists of DSE vented to ESP. | 98 |
| None | a/ | 22 | Carbon steel; modified control device configuration 1 with DSE. Building evaluation and DSE each vented to separate baghouse. | 99 |
| None | 0.9-1.5 | 1.2 | | 99 |
| a/ | a/ | 1.7 | Carbon steel; control device configuration consists of DSE vented to baghouse. | 100 |
| None | a/ | 25-30 | Carbon steel; control device configuration consists of DSE vented to baghouse. | 99 |
| None | a/ | 43 | Carbon steel; control device configuration 2 with motorized monitor louvers to enable closing the monitor to capture fugitive emissions. | 99 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Pro Process production rate |
|---|---|---|---|---|---|
| 58.0 | C | Uncontrolled EAF melting, and refining emissions plus portion of charging, tapping, slagging emissions. | Inland Steel E. Chicago, IN | a/ | a/ |
| .029c/ | C | Controlled EAF melting and refining emissions. | Witteman Steel Mills Fontana, CA | 2/20/75 | 6.2 T steel |
| 0.145c/lb/T scrap melted | C | Controlled EAF melting, refining building evacuation emissions. | TAMCO (Affiliate of Ameron Steel Corp) Etiwanda, California | 3/21/78 | 41.7 T scra melted/hr |
| 1.7d/ lb/T input | C | Controlled EAF melting, refining and building evacuation emissions. | Marathon Steel Tempe, AZ | 4/16/77 | 7.9 T input |
| 0.33d/lb/T input | C | Controlled EAF melting, refining and building evacuation emissions. | Marathon Steel Tempe, AZ | 9/13-16/77 | 18.7 T input |

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin. Test Support Section, OAQPS.
c/ Unclear whether value is based on particulate collected in front half of sampling train or in fro
d/ Based on particulate collected in front half of sampling train.
e/ Based on particulate collected in front and back halves of sampling train.

| Process conditions | | | Test methodology | | | | |
|---|---|---|---|---|---|---|---|
| n | Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology | Percent isokinetic | Sampl tim (mi |
| | a/ | a/ | a/ | a/ | Weighed baghouse catch | a/ | a/ |
| el/hr | 4,290 | a/ | In stack glass filter | In stack after scrubber | Single point sampled | a/ | a/ |
| rap | 549,000 | 119 | Rader Hi-vol. with 3-1/2 in. nozzle | After open baghouse (i.e., no shell around bags) | Sampled 8 random points over top of open baghouse | 103 | a/ |
| ut/hr | 35,800 | 213 | a/ | In stack after old baghouse | a/ | 94.6-99.2 | (54 per |
| put/hr | 146,000 | 161 | a/ | In stack after new baghouse | a/ | 98.2-108.9 | (40 per |

a/ front and back halves combined.

| Test results | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sampling time (min) | Gas flow rate (dscfm) | Number of runs performed | Measured concentrations | | Emission factors | | |
| | | | Range (gr/dscf) | Average (gr/dscf) | Range lb/ton steel | Average lb/ton steel | |
| a/ | a/ | a/ | None | None | 33-83 | 58 | Carbon st configura |
| a/ | a/ | a/ | a/ | 0.005c/ | a/ | 0.029c/ | 1-25 T fu |
| a/ | a/ | a/ | a/ | 0.00128c/ | a/ | 0.145c/ | No sampli being cle whether c made duri |
| (54-57 dscf sampled per run) | | 3 | 0.039-0.049d/ | 0.044d/ | 1.5-1.9d/ | 1.7d/ | Old bagho possibili whether c made duri |
| (40.8-57.4 dscf sampled per run) | | 8 | a/ | 0.0051d/ | a/ | 0.33d/ | New bagho whether c during te |

TABLE 8. (Concluded).

| Test results | | | | |
|---|---|---|---|---|
| centrations | Emission factors | | | |
| Average (gr/dscf) | Range lb/ton steel | Average lb/ton steel | Comments | Reference |
| None | 33-83 | 58 | Carbon steel; control device configuration 2. | 101 |
| 0.005[c]/ | [a]/ | 0.029[c]/ | 1-25 T furnace making carbon steel. | 102 |
| 0.00128[c]/ | [a]/ | 0.145[c]/ | No sampling was performed while bags were being cleaned. 1-120 T furnace; unclear whether carbon or alloy steel was being made during testing. | 103 |
| 0.044[d]/ | 1.5-1.9[d]/ | 1.7[d]/ | Old baghouse on furnace #1 (120 T capacity); possibility of leaking bags; unclear whether carbon or alloy steel was being made during testing. | 104 |
| 0.0051[d]/ | [a]/ | 0.33[d]/ | New baghouse on furnaces #2 and #3; unclear whether carbon or alloy steel was being made during testing. | 104 |

| Average emission factor (lb/ton steel) | Emission factor reliability | Source | Company/ location | Test date | Process condition: Process production rate | Process condition: Gas flow rate (dscfm) |
|---|---|---|---|---|---|---|
| 5.3c/ | C | Uncontrolled OHF melting, and refining emissions. | Company A (AISI data) | 7/5-6/73 | 3,840 T/day | 301,000 |
| 0.64c/ | C | Controlled OHF melting and refining emissions | Company A (AISI data) | 7/5-6/73 | 3,840 T/day | 301,000 |
| 0.28d/ | A b/ | Controlled OHF melting and refining emissions | Company A (AISI data) | 6/25-27/74 | 4,750-5,012 T/day | 296,000-326,000 |
| 0.1c/ | B | Controlled OHF melting and refining emissions. | Company N (AISI data) | 3/20/72 | 176 T steel/hr | 534,000 |
| 0.33c/reported<br>0.45c/average | C<br>C | Controlled OHF melting and refining emissions. | Company C (AISI data) | 5/16-26/71 | 27 T steel/hr/ furnace | 94,500 |
| 0.168 weighted by sampling time above and between furnaces | C | Roof monitor emissions | Company F (AISI data) | 6/14-18/73 | 125 T steel/hr | 1,117,000 acfm (tota flow above and on eit side of on furnace) |
| 23.7d/ducted emissions avg during charging and blowing;<br>0.5d/avg during charging;<br>21.1d/avg during blowing. | A<br>A<br>A | Uncontrolled OHF melting and refining emissions | United States Steel, Fairfield, AL | 9/30/75 10/1-2/75 | 30 T steel/ hr/furnace | 52,600 |

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
c/ Unclear whether value represents particulate collected in front half of sampling train or in front
d/ Based on particulate collected in front half of sampling train.

| cess conditions | | Test methodology | | |
|---|---|---|---|---|
| Gas flow rate (dscfm) | Gas temp. (°F) | Type of sampling device | Location of sampling device | Sampling methodology |
| 301,000 | 350 | a/ | Precipitator inlet | a/ |
| 301,000 | a/ | a/ | Precipitator outlet | a/ |
| 296,000-326,000 | 430-450 | EPA Method 5 sampling train | In 12 ft Ø precipitator exit stack | EPA Method 5 |
| r 534,000 | 385 | Western precipitation stack sampling train. In-stack thimble. | In 16.5 ft Ø precipitator exit stack | WP-50 |
| r/ 94,500 | a/ | a/ | a/ | a/ |
| hr 1,117,000 acfm (total flow above and on either side of one furnace) | 118 above furnace; 102 between furnaces | a/ | In roof monitor over one furnace and between two furnaces | Profiled velocity 19 ft wide monitor vane type anemomet Unknown particle c centration measuri technique. |
| 52,600 | 608 | In-stack alundum thimble followed by heated cyclone and filter outside stack. | In 88 in. Ø stack | Modified EPA Meth |

n or in front and back halves combined.

| | | | | Test result | |
|---|---|---|---|---|---|
| | | | | Measured concentrations | |
| Percent isokinetic | Sampling time (min) | Sampling flow rate (dscfm) | Number of runs performed | Range (gr/dscf) | Average (gr/dscf) |
| a/ | a/ | a/ | 8 | 0.14-0.58c/ | 0.33c/ |
| a/ | a/ | a/ | 2 | 0.02-0.05c/ | 0.04c/ |
| 103-104 | 144 | 0.57 | 3 | 0.015-0.029d/ | 0.022d/ |
| a/ | 180 | 0.55 | 1 | None | 0.004c/ |
| a/ | a/ | a/ | 24 | 0.0055-0.037c/ | 0.015c/ |
| 65% of the data was more than 10% above isokinetic. | 8-75 (tests conducted during various segments of the operation such as refining, scrap melt, etc.) | 0.3-0.4 acfm | 28 | 0.000639-0.0116 gr/acf (above furnace) 0.000881-0.0045 gr/acf (between furnaces) | 0.00504 gr/acf (above furnace) 0.00261 gr/acf (between furnaces) |
| 98.4-104.4 | 126-236 | 0.66 | 3 | 0.8685-1.5429d/ | 1.4101d/ |

TABLE 9. SUMMARY OF EMISSION FACTORS FOR OPEN HEARTH FURNACES

| Test results | | | | |
|---|---|---|---|---|
| trations | Emission factors | | | |
| Average (gr/dscf) | Range (lb/ton steel) | Average (lb/ton steel) | Comments | Reference |
| 0.33c/ | 2.2-9.4c/ | 5.3c/ | 8 furnaces in operation. | 105 |
| 0.04c/ | 0.32-0.81c/ | 0.64c/ | 8 furnaces in operation | 105 |
| 0.022d/ | 0.18-0.36d/ | 0.28d/ | 10-11 furnaces in operation; 3-4 furnaces were being blown. | 106 |
| 0.004c/ | None | 0.1c/ | 6 furnaces with $O_2$ lances | 107 |
| 0.015c/ | 0.16-1.1c/ | 0.45c/ | Venturi scrubber pressures from 25 to 47 in. $H_2O$. | 108 |
| 0.00504 gr/acf (above furnace) 0.00261 gr/acf (between furnaces) | 0.07-0.64 (various segments of the operation as measured above furnace) | 0.22 avg. of the entire operation as measured above furnace. | Only iron oxide was collected. No kish was deposited on filters. | 109 |
| | 0.029-0.12 (various segments of the operation as measured between furnaces) | 0.063 avg of entire operation as measured between furnaces | | |
| 1.4101d/ | 12.3-30.8d/ | 23.7d/ | Only two tests were performed for charging and blowing alone while three were performed for charging and blowing combined. | 110 |

The results of the tests on the teeming of leaded steel are shown in Table 10. The average uncontrolled emission factor measured by the front half of a Method 5 train was 0.81 lb/ton steel teemed. The average controlled emission factor measured by the front half of a Method 5 train after the baghouse was 0.0038 lb/ton steel teemed. The average EFs are given an A rating.

The results of six tests on the teeming of unleaded steel are shown in Table 11. The average uncontrolled emission factor measured by the front half of a Method 5 train was 0.07 lb/ton steel teemed. The average controlled emission factor measured by the front half of a Method 5 train after the baghouse was 0.0016 lb/ton steel teemed. These average EFs are given an A rating.

## 3.8 SCARFING

Particulate emissions occur when semi-finished steel products are manually or machine scarfed to remove surface defects. Table 12 lists controlled and uncontrolled EFs for machine scarfing. There are seven A-rated, five B-rated, and three unrateable EFs.

In comparing hand scarfing EFs to machine scarfing EFs, one must consider the units of the EFs and the process differences. The units for the machine scarfing EFs are a pound of particulate per ton of steel put through the machine. In machine scarfing, the entire surface of the product is removed to a depth that is dependent on the speed of the product through the machine and on the flame temperature. Hand scarfing does not involve removal of an entire surface but rather only spots on the product are scarfed.

If hand and machine scarfing were compared on a pound of particulate per ton of material removed basis, then one might, as a first estimate, assume that the hand scarfing EF can be likened in quantity to uncontrolled machine scarfing. But if the comparison is performed on the basis of pound of particulate per ton of steel put through the process, it is believed that hand scarfing is significantly less than uncontrolled machine scarfing. Unfortunately, no test data are available to support this assumption for hand scarfing emissions.

## 3.9 MISCELLANEOUS COMBUSTION SOURCES

Miscellaneous combustion sources include the burning of blast furnace gas, coke oven gas, natural gas, No. 6 fuel oil, or coal for heat used in boilers, soaking pits, and slab furnaces.

TABLE 10. EMISSIONS FROM LEADED STEEL TEEMING AT WISCONSIN STEEL, CHICAGO, ILLINOIS - SUMMARY OF TEST PROCEDURES AND RESULTS

| Variable | Baghouse inlet | Baghouse outlet |
|---|---|---|
| Test date | April and May, 1978 | April and May, 1978 |
| Process production rate (T/min of teeming operation[a]) | 5.1-5.4 | 5.1-5.4 |
| Gas flowrate (dscfm) | 28,000-42,600[b] | 56,600[b] |
| Gas temperature (°F) | 90-127 | 78-118 |
| Gas velocity (fpm) | 2,760-4,240 | 3,070-3,800 |
| Type of sampling device | Method 5 train | Method 5 train |
| Location of sampling device | In 6' Ø BH inlet duct | In 3' Ø BH outlet duct |
| Sampling methodology | EPA Method 5. 24 pts sampled per test. | EPA Method 5. 36 pts sampled per test. |
| Percent isokinetic | 100.3-101.1 | 95.4-103.1 |
| Sampling time per run (min) | 24 | 27-29 |
| Sampling flowrate (dscfm) | 2.6-4.0 | 4.5-5.0 |
| Number of runs performed | 3 | 3 |
| Range/average of front half concentrations measured (gr/dscf) | 0.6794-1.0877 (0.8172) | 0.0012-0.0033 (0.0025) |
| Range/average of combined front and back half concentrations (gr/dscf) | 0.6918-1.0968 (0.8285) | 0.0103-0.0155 (0.0135) |
| Range/average of front half emission factors (lb/T steel teemed) | 0.51-1.14 (0.81) | - (0.0038) |
| Average of combined front and back half emission factors (lb/T steel teemed) | 0.81 | 0.021 |

a/ The averaging time began with the initiation of teeming into the first mold and ended with the conclusion of teeming into the last mold.

b/ Some of the flow rate data were incomplete since velocity traverses were not completed. It still appears, through, that there was a leak in the collection system that will cause the outlet concentrations to be reported lower than actual. However, this problem will not affect the emission factor values.

TABLE 11. EMISSIONS FROM UNLEADED STEEL TEEMING AT WISCONSIN STEEL, CHICAGO, ILLINOIS - SUMMARY OF TEST PROCEDURES AND RESULTS

| Variable | Baghouse inlet | Baghouse outlet |
|---|---|---|
| Test date | April and May, 1978 | April and May, 1978 |
| Process production rate (T/min of teeming operation[a]) | 3.8-5.9 | 3.8-5.9 |
| Gas flowrate (dscfm) | 38,700-44,700[b] | 40,100-44,800[b] |
| Gas temperature (°F) | 81-101 | 88-92 |
| Gas velocity (fpm) | 4,860-6,060 | 2,450-3,530 |
| Type of sampling device | Method 5 train | Method 5 train |
| Location of sampling device | In 6' Ø BH inlet duct | In 3' Ø BH outlet duct |
| Sampling methodology | EPA Method 5. 24 pts sampled per test. | EPA Method 5. 36 pts sampled per test. |
| Percent isokinetic | 97.2-108.1 | 92.1-108.9 |
| Sampling time per run (min) | 20-24 | 24-30 |
| Sampling flowrate (dscfm) | 3.7-4.1 | 3.6-4.6 |
| Number of runs performed | 6 | 6 |
| Range/average of front half concentrations measured (gr/dscf) | 0.035-0.068 (0.0565) | 0.004-0.0028 (0.0011) |
| Range/average of combined front and back half concentrations (gr/dscf) | 0.0375-0.0753 (0.061) | 0.0039-0.0133 (0.0067) |
| Range/average of front half emission factors (lb/T steel teemed) | 0.04-0.11 (0.07) | - (0.0016) |
| Average of combined front and back half emission factors (lb/T steel teemed) | 0.076 | 0.0093 |

a/ The averaging time began with the initiation of teeming into the first mold and ended with the conclusion of teeming into the last mold.

b/ Some of the flow rate data were incomplete since velocity traverses were not completed.

| Average emission factor (lb/ton metal scarfed) | E.F. reliability | Company/ location | Scarfer designation | Test date | Process parameters: Tons scarfed per hr | Process parameters: Emission control system | Process parameters: Gas flow rate (dscfm) |
|---|---|---|---|---|---|---|---|
| 0.08c/ | A[b/] | Company A (AISI data) | 40 in. bloom | 2/76 | 60 | ESP | 69,900 |
| 0.001c/ | A[b/] | | 46 in. slab | 10/75 | 486 | ESP | 69,900 (wet scfm) |
| 0.008c/ | A[b/] | | 24 in. billet | 10/75 | 147 | ESP | 17,000 (wet scfm) |
| 0.032c/ | A[b/] | | 18 in. billet No. 1 | 10/75 | 105 | ESP | 18,700 |
| 0.014c/ | A[b/] | | 18 in. billet No. 2 | 10/75 | 89 | ESP | 19,300 |
| 0.003c/ | A[b/] | | Rail-mill | 11/75 | 111 | ESP | 11,300 |
| 0.10 | B | | 46 in. slab | 1/67 | 207 | - | 72,700 |
| 0.087d/ | A[b/] | | Blooming mill | 7/74 | 275 | - | 31,600 |
| a/ | a/ | Company B (AISI data) | No. 3 slabbing mill | 5/73 | a/ | - | 95,500 |
| a/ | a/ | Company C (AISI data) | a/ | 1/66 | 200 | - | 62,800 |
| a/ | a/ | | a/ | 1/66 | 200 | Kinpactor | 62,800 |
| 0.22d/ | B | | a/ | 8/71 | 98.8 | - | 22,700 ACFM |

TABLE 12. SUMMARY OF EMISSION FACTORS FOR SCARFIN

| Ca... | Test methodology | | | | Average measured concentration (gr/dscf) | Average emission factor (lb/ton metal scarfed) | Comments |
|---|---|---|---|---|---|---|---|
| tem... | Sampling methodology | No. of runs | Sample time (min) | Percent isokinetic | | | |
| (1) | | | | | | | |
| 80 | EPA-5 | 3 | 120 | 99.7-100.7 | 0.008c/ | 0.08c/ | After ESP |
| 82 | EPA-5 | 3 | 140 | 99.1-100.5 | 0.001c/ | 0.001c/ | After ESP |
| 84 | EPA-5 | 3 | 140 | 97.5-99.4 | 0.003c/ | 0.008c/ | After ESP |
| 77 | EPA-5 | 1 | 140 | 96.8-98.9 | 0.007c/ | 0.032c/ | After ESP |
| 80 | EPA-5 | 3 | 140 | 98.2-100.3 | 0.002c/ | 0.014c/ | After ESP |
| 96 | EPA-5 | 3 | 140 | 99.9-101.1 | 0.002c/ | 0.003c/ | After ESP |
| 80 | WP-50 | 3 | 3-41 a/ | | 0.25d/ | 0.1d/ | Uncontrolled-sampl only while slabs w being scarfed. Ac zero emissions bet |
| 110 | EPA-5 | 3 | 14... | 98-101 | 0.089d/ | 0.087d/ | Uncontrolled; conc represents combine scarfing periods. |
| 114 | ASME PTC-21.27 | 3 | 89-150 | a/ | 0.14d/ | a/ | Uncontrolled |
| 140 | a/ | 3 | 130-180 | a/ | 0.57d | a/ | Uncontrolled; conc may or may not be to scarfing period |
| 135 | a/ | 3 | 130-180 | a/ | 0.04 | a/ | After Kinpactor an R rotocleone. |
| 130 | EPA-5 | 3 | 4 | a/ | 0.54d/ | 0.22d/ | Uncontrolled; sam during scarfing. |

TABLE 12. SUMMARY OF EMISSION FACTORS FOR SCARFING OPERATIONS

| Percent isokinetic | Average measured concentration (gr/dscf) | Average emission factor (lb/ton metal scarfed) | Comments | References |
|---|---|---|---|---|
| 99.7-100.7 | 0.008c/ | 0.08c/ | After ESP | 111 |
| 99.1-100.5 | 0.001c/ | 0.001c/ | After ESP | 112 |
| 97.5-99.4 | 0.003c/ | 0.008c/ | After ESP | 112 |
| 96.8 -98.9 | 0.007c/ | 0.032c/ | After ESP | 112 |
| 98.2-100.2 | 0.002c/ | 0.014c/ | After ESP | 112 |
| 99.9-101.1 | 0.002c/ | 0.003c/ | After ESP | 113 |
| a/ | 0.25d/ | 0.1d/ | Uncontrolled-sampled only while slabs were being scarfed. Assumed zero emissions between scarfs. | 114 |
| 98-103 | 0.089d/ | 0.087d/ | Uncontrolled; concentration probably represents combined scarfing and non-scarfing periods. | 115 |
| a/ | 0.14e/ | a/ | Uncontrolled | 116 |
| a/ | 0.570 | a/ | Uncontrolled; concentration may or may not be converted to scarfing period only. | 116 |
| a/ | 0.04 | a/ | After Kinpactor and Type R rotoclone. | 117 |
| a/ | 0.54d/ | 0.22d/ | Uncontrolled; sampled only during scarfing. | |

| Average emission factor (lb/ton metal scarfed) | E.F. reliability | Company/ location | Scarfer designation | Test date | Process parameters: Tons scarfed per hr | Process parameters: Emission control system | Process parameters: Gas flow rate (dscfm) | C |
|---|---|---|---|---|---|---|---|---|
| 0.24d/ | B | | a/ | 8/71 | 112.5 | - | 10,500 ACFM | 8 |
| 0.10e/ | B | Company Q (AISI data) | Blooming mill | 9/73 | 125 | Scrubber | a/ | a |
| 0.07c/ | B | | a/ | 3/73 | 236.5 | a/ | a/ | a |

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
c/ Based on particulate measured in front half of sampling train.
d/ Unclear whether value represents particulate captured in front half of sampling train or in front and
e/ Based on particulate measured in front and back halves of sampling train.

TABLE 12. (CONCLUDED)

| ple ime in) | Percent isokinetic | Average measured concentration (gr/dscf) | Average emission factor (lb/ton metal scarfed) | Comments | Reference |
|---|---|---|---|---|---|
| 0 | a/ | 0.34d/ | 0.24d/ | Uncontrolled; sampled during scarfing and non-scarfing. | 117 |
| 6 | a/ | | 0.11e/ | After scrubber. | 118 |
| 0 | a/ | 0.035c/ | 0.07c/ | Unclear whether controlled or uncontrolled. | 119 |

The EFs to be used for burning natural gas, No. 6 fuel oil, or coal in boilers can be acquired from AP-42 as follows:

| Fuel | Uncontrolled emission factor | Rating |
|---|---|---|
| Bituminous coal | 16 A lb/ton coal (A is ash content in percent; assume 10%) | A |
| No. 6 fuel oil | 10 (S) + 3 lb/1,000 gal. (S is sulfur content in percent by weight; assume 1%) | A |
| Natural gas | 10 lb/$10^6$ $ft^3$ | A |

The EFs for burning of the above fuels in soaking pits or slab furnaces can be estimated to be the same as those for boilers, but since this is an estimate, the rating would drop to D.

The EFs for blast furnace gas and coke oven gas have not been researched by experimentation. The EFs must therefore be acquired by estimation. There are three facts available in making the estimation. First, the gas exiting the blast furnace passes through primary and secondary cleaners and can be cleaned to less than 0.02 gr/$ft^3$ (2.86 lb/$10^6$ $ft^3$).[120] Second, nearly one-third of coke oven gas is methane. Third, there are no constituents of blast furnace gas that generate particulate when burned.[121] The combustible constituent of blast furnace gas is CO which burns clean.

Based on the above three facts, the EFs for burning blast furnace gas can be estimated. The EF for burning blast furnace gas is assumed to equal the particulate carried into the burning process with the fuel plus the particulate generated in burning the fuel. The particulate carried in with blast furnace gas is 2.86 lb/$10^6$ $ft^3$. There is no appreciable amount of particulate generated in burning blast furnace gas since there is no particulate generating combustible gas in it. Consequently, the EF for burning blast furnace gas is estimated at 2.86 lb/$10^6$ $ft^3$.

The EF for burning coke oven gas can be estimated in the same fashion. Assuming that cleaned coke oven gas has as much particulate in it initially as cleaned blast furnace gas, the particulate carried in with coke oven gas is estimated at 2.86 lb/$10^6$ $ft^3$. Since one-third of coke oven gas is methane, the main component of natural gas, it is assumed that the burning of coke oven gas generates one-third the particulate that the burning of natural gas does, i.e., 3.33 lb/$10^6$ $ft^3$. Thus, the EF for burning coke oven gas is estimated at 6.2 lb/$10^6$ $ft^3$.

Also necessary for calculations is the heating value of each fuel. The following is a list of heating values and the reference from which they were obtained:

| Fuel | Heating value (sensible heat) | Reference |
|---|---|---|
| Blast furnace gas | 75-90 Btu/ft$^3$ | 122 |
| Coke oven gas | 500 Btu/ft$^3$ | 123 |
| No. 6 fuel oil | 141,000 Btu/gal. | 124 |
| Bituminous coal | 25 million Btu/ton | 125 |
| Natural gas | 1,000 Btu/ft$^3$ | 126 |

Putting the EFs into similar units yields the following table:

| Fuel | Uncontrolled emission factor (lb/10$^6$ Btu) | Emission factor reliability | | |
|---|---|---|---|---|
| | | Boilers | Soaking pits | Slab furnaces |
| Blast furnace gas | 0.035 | D | D | D |
| Coke oven gas | 0.012 | D | D | D |
| No. 6 fuel oil | 0.09 | A | D | D |
| Bituminous coal | 6.4 | A | D | D |
| Nacural gas | 0.01 | A | D | D |

## 3.10 OPEN DUST SOURCES

In addition to process sources, open dust sources contribute to the atmospheric particulate burden. Open dust sources at iron and steel plants include vehicular traffic on paved and unpaved roads, loading into and loading from storage piles, storage pile maintenance, and storage pile and exposed area wind erosion.

### 3.10.1 Identification of Emission Sources

Emissions occur when vehicles travel on unpaved surfaces. Such vehicles as passenger cars, pick-up trucks, haul trucks, and delivery trucks all produce emissions as the tires interact with the road. The heavier the vehicle, all other variables being the same, the more emissions one can expect.

Emissions occur when vehicles traveling on paved roads elevate dust from the road surface. The dust is deposited on the road surface by carry-on, pavement wear, tire wear, and erosion from adjacent areas, to name a few points of origin.

As stated above, storage piles are also sources of dust. Dust producing mechanical activities include:

1. Unloading of raw materials from a barge by a clamshell or bucket wheel and from a railcar by dumping.

2. Adding material to a storage pile via stacker, loader, or truck.

3. Loading of material from the pile onto a conveyor or into a truck.

4. Maintenance of pile shape with loaders or dozers.

In addition to mechanical activities which produce dust, natural activities such as wind erosion occur. Particulate is generated from exposed areas and storage piles where wind speed exceeds the threshold velocity which for some materials is about 12 mph at 1 ft above the surface.[127]

Finally, emissions occur when material drops from one conveyor to another. This is the standard procedure for changing transport direction. It is thought that little emissions occur elsewhere in the conveying process. The belts themselves rest on idler rolls which cause the belts to incline upward 20 or 30 degrees on both edges. This provides a shield from the wind and minimizes spillage.

### 3.10.2 Quantification of Emission Factors

Empirically derived predictive EF equations for open dust sources have been developed by Midwest Research Institute (MRI).[127-130] The predictive equations have been modified as more tests have been added to the data base. A summary of the most currently refined predictive equations is shown in Table 13.

The predictive EFs listed in Table 13 can be used for, but are not limited to, iron and steel plants. Table 14 shows the quality assurance rating currently assigned to the EFs for each of the source categories listed in Section 3.10.1. While many of the emission factors are rated A or B when applied to the source categories listed in Table 14, the rating would be lowered for some of the factors if controlled emission factors were to be predicted. For example, the effects of watering and chemical dust suppressants on the emissions from vehicles traveling on unpaved roads are not well known.

Some of the correction parameters in Table 13 can be determined from published literature. Vehicle weight and dumping device capacity, for example, can be found in manufacturer literature. Mean wind speed, number of dry days, and percent of time the wind speed exceeds 12 mph at 1 ft above the ground can be found in the Climatic Atlas[131] or from other local weather stations. The precipitation-evaporation index has been calculated by MRI for all the state

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## TABLE 13. FUGITIVE DUST EMISSION FACTORS EXPERIMENTALLY DETERMINED BY MRI

| Source category | Measure of extent | Emission factor[a] (lb/unit of source extent) | Correction Parameters |
|---|---|---|---|
| 1. Unpaved roads | Vehicle-Miles Traveled | $5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{d}{365}\right)$ | s = Material Silt Content (%) |
| 2. Paved Roads | Vehicle-Miles Traveled | $0.09\ I\left(\frac{s}{10}\right)\left(\frac{S}{30}\right)\left(\frac{L}{1,000}\right)\left(\frac{W}{3}\right)^{0.7}$ | S = Average Vehicle Speed (mph) |
| 3. Batch Load-In (e.g., front-end loader, railcar dump) | Tons of material loaded in | $0.0018\ \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$ | W = Vehicle Weight (tons) |
| 4. Continuous Load-In (e.g., stacker, transfer station) | Tons of Material Loaded In | $0.0018\ \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}}$ | L = Surface Dust Loading on Traveled Portion of Road (lb/mile) |
| 5. Active Storage Pile Maintenance and Traffic | Tons of Material Put Through Storage | $0.10\ K\ \frac{s}{1.5}\left(\frac{d}{235}\right)$ | U = Mean Wind Speed (mph) |
| 6. Active Storage Pile Wind Erosion | Tons of Material Put Through Storage | $0.05\left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)\left(\frac{D}{90}\right)$ | M = Material Surface Moisture Content (%) |
| 7. Batch Load-Out | Tons of Material Loaded Out | $0.0018\ \frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$ | Y = Dumping Device Capacity ($yd^3$) |
| 8. Wind Erosion of Exposed Areas | Acre-Years of Exposed Land | $3,400\ \frac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P-E}{50}\right)^{2}}$ | K = Activity Correction[b] |
| | | | d = Number of Dry Days Per Year |
| | | | f = Percentage of Time Wind Speed Exceeds 12 mph at 1 ft above the ground |
| | | | D = Duration of Material Storage (days) |
| | | | e = Surface Erodibility (tons/acre/year) |
| | | | P-E = Thornthwaite's Precipitation-Evaporation Index |
| | | | N = Number of Traveled Lanes |
| | | | I = Industrial Road Augmentation Factor[c] |
| | | | w = Average Number of Wheels on Vehicle Mix |
| | | | h = Drop Height (ft) |

a/ Represents particulate smaller than 30 μm in diameter based on particle density of 2.5 $g/cm^3$.

b/ Equals 1.0 for front-end loader maintaining pile tidiness and 50 round trips per truck per day in the storage area.

c/
* Equals 7.0 for trucks coming from unpaved to paved roads and releasing dust from underbody of vehicle;
* Equals 3.5 when 20% of the vehicles are forced to travel temporarily with one set of wheels on an unpaved road berm while passing on narrow roads;
* Equals 1.0 for traffic entirely on paved surfaces.

TABLE 14. EMISSION FACTOR QUALITY ASSURANCE LIMITATIONS
(Effective September 1979)

| Source category | Quality assurance rating |
|---|---|
| Vehicular Traffic on Unpaved Roads - Dry Conditions | A |
| Vehicular Traffic on Unpaved Roads - Controlled Conditions | C |
| Vehicular Traffic on Paved Roads | B |
| Storage Pile Formation by Means of Translating Conveyor Stacker | B |
| Transfer of Aggregate from Loader to Truck | B |
| Storage Pile Maintenance and Related Traffic | C |
| Wind Erosion from Storage Piles and Exposed Areas | C |

climatic regions in the United States and is reported in published literature.[127] The erodibility of materials can also be obtained from published literature.[132]

Some of the correction parameters in Table 13 can be determined with reasonable accuracy by estimation. Average vehicle speed and number of wheels can be estimated. The number of traveled paved road lanes can be estimated for a particular iron and steel plant by plant personnel. The drop height for aggregate material can be measured or visually estimated with reasonable accuracy.

Finally, there are correction parameters in Table 13 that can best be estimated by MRI personnel. These parameters are raw material silt and moisture content, paved and unpaved road material silt content, and total surface dust loading on paved roads.

Tables 15 through 17 show the results of silt, moisture, and loading analysis of field samples collected by MRI. For each type of material, the number of samples obtained, the range of values measured, and the mean values for these correction parameters are given. Samples listed in Tables 15 through 17 were collected at as many as 12 different iron and steel plants in a wide range of geographic locations.

TABLE 15. SILT CONTENT VALUES APPLICABLE IN THE IRON AND STEEL INDUSTRY

| Source | Number of tests | Range of silt content (%) | Average silt content (%) |
|---|---|---|---|
| 1. Unpaved roads | 12 | 4-13 | 7.3 |
| 2. Paved roads | 9 | 1.1-13 | 5.9 |
| 3. Material handling activities and storage pile wind erosion | | | |
| a. Coal | 7 | 2-7.7 | 5.0 |
| b. Iron ore pellets | 10 | 1.4-13 | 4.9 |
| c. Lump iron ore | 9 | 2.8-19 | 9.5 |
| d. Coke breeze | 1 | - | 5.4 |
| e. Slag | 3 | 3.0-7.3 | 5.3 |
| f. Blended ore | 1 | - | 15.0 |
| g. Sinter | 1 | - | 0.7 |
| h. Limestone | 1 | - | 0.4 |
| i. Flue dust | 2 | 14-23 | 18.0 |

TABLE 16. SURFACE MOISTURE CONTENT VALUES APPLICABLE IN THE IRON AND STEEL INDUSTRY

| Source | Number of tests | Range of surface moisture content (%) | Average surface moisture content (%) |
|---|---|---|---|
| 1. Material handling activities and storage pile wind erosion | | | |
| a. Coal | 6 | 2.8-11 | 4.8 |
| b. Iron ore pellets | 8 | 0.64-3.5 | 2.1 |
| c. Lump iron ore | 6 | 1.6-8.1 | 5.4 |
| d. Coke breeze | 1 | - | 6.4 |
| e. Slag | 3 | 0.25-2.2 | 0.92 |
| f. Blended ore | 1 | - | 6.6 |
| g. Flue dust | 1 | - | 12.4 |

TABLE 17. SURFACE LOADING ON TRAVELED LANES OF PAVED ROADS IN IRON AND STEEL PLANTS

| Number of tests | Range of surface loading (lb/mile) | Average surface loading (lb/mile) |
|---|---|---|
| 9 | 65-17,000 | 2,700 |

## SECTION 4.0

## DEVELOPMENT OF REPRESENTATIVE EMISSION FACTORS

The final objective of this report is to develop a representative EF value or predictive equation for each particulate emission source in the iron and steel industry. Section 3.0 presents all the EF data presently available. It is from the data in Section 3.0 that the representative EF values were developed.

### 4.1 PROCESS STACK AND FUGITIVE EMISSIONS

Table 18 shows a summary of the EFs by source and by reliability rating. (The rating system was defined in Section 3.0). Recalling that nearly every EF in the left-hand column of Tables 2 through 10 represents an average of a number of runs (test series), the average of these test series average values as presented in Table 18 was calculated as follows:

$$EF_{avg} = \sum_{i=1}^{i=T} EF_i \; N_i \Big/ \sum_{i=1}^{i=T} N_i \qquad (1)$$

$EF_i$ = average of test series i,

$N_i$ = number of runs in test series i (if $N_i > 3$, then set $N_i = 3$),

$T$ = number of test series, and

$EF_{avg}$ = emission factor average for a specific reliability rating category.

The philosophy behind Equation 1 is that within the same rating category the test series composed of the most runs should receive the most weight. However, a limit to the weighting is set at a value of 3. This is to eliminate the possibility that a very high number of tests performed at a very dirty or very clean, and consequently nonrepresentative, plant could unfairly weight the overall average. Thus, a test series with three tests will be weighted three times that with only one test while the possibility of a nonrepresentative plant with many tests distorting the overall average is eliminated.

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# TABLE 18. SELECTION OF SINGLE EMISSION FACTOR VALUES TO REPRESENT EACH PARTICULATE SOURCE CATEGORY IN THE IRON AND STEEL INDUSTRY

| Source | Test series: Rating | Test series: Average EF ($EF_i$) | Test series: EF units | Test series: Number of runs | Test series: Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value: Average | Calculated single EF value: Range | Calculated single EF value: Rating |
|---|---|---|---|---|---|---|---|---|---|
| I. By-product Coke Ovens | | | | | | | | | |
| A. Coal Charging | | | lb/T coal | | | | | | |
| 1. Uncontrolled | C | 0.11 | | 10 | 141 | 0.21 | 0.85 | 0.11-1.5 | C |
| | C | 0.52 | | ?-assume 1 | 6 | | | | |
| | D | 1.5 | | ?-assume 1 | 5 | 1.5 | | | |
| 2. Controlled | | | | | | | | | |
| a. Larry car vented to scrubber | C | 0.02 | | ?-assume 1 | 6 | 0.02 | 0.02 | | C |
| b. Sequential charging | C | 0.016 | | 4 | 141 | 0.016 | 0.016 | | C |
| B. Uncontrolled Door Leaks | A | 0.44 | lb/T coal | 1 | 8 | 0.58 | 0.51 | 0.36-0.72 | B |
| | | 0.72 | | 1 | 9 | | | | |
| | B | 0.36 | | 1 | 7 | 0.36 | | | |
| C. Coke Pushing | | | lb/T coal | | | | | | |
| 1. Uncontrolled Suspended Emissions (as measured in duct venting coke side shed) | A | 0.69 | | 1 | 8,12 | 0.5 | 0.47 | 0.25-0.68 | A |
| | | 0.55 | | 4 | 13 | | | | |
| | | 0.25 | | 1 | 9,12 | | | | |
| | B | 0.68 | | 2 | 11 | 0.4 | | | |
| | | 0.29 | | 28 | 15 | | | | |
| | | 0.26 | | 4 | 15 | | | | |
| | | 0.34 | | 2 | 17 | | | | |
| | | 0.43 | | 2 | 17 | | | | |
| | | 0.53 | | 23 | 12 | | | | |
| | | 0.32 | | 2 | 12 | | | | |
| | C | 0.49 | | 1 | 11 | 0.49 | | | |
| 2. Controlled Suspended Emissions | | | | | | | | | |
| a. Water sprays | A | 0.39 | | 15 | 13 | 0.39 | 0.39 | | A |
| 3. Uncontrolled Total Emissions (suspended plus dustfall) | A | 2.3 | | 9 | 16 | 2.3 | 2.0 | 0.7-2.3 | B |
| | B | 2.0 | | 39 | 10 | 1.4 | | | |
| | | 0.7 | | 25 | 10 | | | | |
| | C | 0.4 | | 6 | 16 | 0.4 | | | |
| 4. Controlled Total Emissions (suspended plus dustfall) | | | | | | | | | |
| a. Water sprays | B | 1.2 | | 15 | 13 | 1.2 | 1.2 | | B |
| b. Enclosed coke car and guide vented to scrubber | C | 0.024 | | 6 | 16 | 0.024 | 0.024 | | C |

(continued)

## TABLE 18. (continued)

| Source | Rating | Average EF ($EF_i$) | Test series: EF units | Number of runs | Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value: Average | Range | Rating |
|---|---|---|---|---|---|---|---|---|---|
| D. Quenching | | | lb/T coal | | | | | | |
| 1. Controlled by Baffles | A | 1.4 | | 13 | 18,19 | 1.0 [a] | 1.0 [a] | 0.21-2.6 | A |
| | | 2.6 | | 12 | 18,19 | | | | |
| | | 0.25 | | 9 | 21 | | | | |
| | | 0.21 | | 2 | 21 | | | | |
| | | 0.23 | | 6 | 21 | | | | |
| | C | 0.04 | | ?-assume 1 | 22 | 0.04 | | | |
| E. Uncontrolled Combustion Stacks | B | 0.35 | lb/T coal | 1 | 23 | 0.58 | 0.58 | 0.08-1.31 | B |
| | | 0.53 | | 1 | 23 | | | | |
| | | 1.31 | | 42 | 23 | | | | |
| | | 0.36 | | 2 | 23 | | | | |
| | | 1.04 | | 2 | 23 | | | | |
| | | 0.08 | | 4 | 25 | | | | |
| | | 0.46 | | 3 | 23 | | | | |
| | | 0.36 | | 1 | 23 | | | | |
| | | 0.42 | | 2 | 23 | | | | |
| | | 0.74 | | 1 | 23 | | | | |
| | | 0.18 | | 2 | 23 | | | | |
| | | 0.43 | | 5 | 23 | | | | |
| | | 0.42 | | 1 | 23 | | | | |
| | | 0.9 | | 1 | 23 | | | | |
| | | 0.53 | | 1 | 23 | | | | |
| | | 0.82 | | 1 | 23 | | | | |
| | C | 0.16 | | 2 | 23 | 0.55 | | | |
| | | 0.12 | | 1 | 23 | | | | |
| | | 0.7 | | 10 | 24 | | | | |
| | | 0.8 | | 10 | 24 | | | | |
| F. Coal Preheaters | | | lb/T coal | | | | | | |
| 1. Uncontrolled | C | 7.0 | | 18 | 135 | 7.0 | 7.0 | | C |
| 2. Controlled by Scrubber | C | 0.65 | | 18 | 135 | 0.65 | 0.65 | | C |
| II. Blast Furnaces | | | | | | | | | |
| A. Slips | D | | lb/slip | | 26 | 87.0 | 87.0 | 27.6-276 | D |
| B. Uncontrolled Cast House Emissions | | | lb/T hot metal | | | | | | |
| 1. Monitor | A | 0.78 | | 2 | 29 | 0.78 | 0.6 | 0.2-0.78 | B |
| | B | 0.2 | | 19 | 29 | 0.25 | | | |
| | | 0.31 | | 10 | 30 | | | | |
| | C | 0.25 | | ?-assume 1 | 29 | 0.39 | | | |
| | | 0.52 | | ?-assume 1 | 29 | | | | |
| 2. Tap Hole and Trough (not runners) | B | 0.31 | | 3 | 28 | 0.3 | 0.3 | 0.29-0.31 | B |
| | | 0.29 | | 1 | 28 | | | | |

(continued)

## TABLE 18. (continued)

| Source | Test series: Rating | Average EF ($EF_i$) | EF units | Number of runs | Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value: Average | Range | Rating |
|---|---|---|---|---|---|---|---|---|---|
| III. Sintering | | | | | | | | | |
| A. Windbox Emissions | | | lb/T sinter | | | | | | |
| 1. Uncontrolled | | | | | | | | | |
| a. Leaving grate | B | 10.8 | | 17 | 31 | 11.1 | 11.1 | 10.8-11.8 | B |
| | | 11.8 | | 6 | 33 | | | | |
| b. After coarse particulate removal | A | 8.7 | | 10 | 35 | 8.7 | 8.7 | | A |
| 2. Controlled by Dry ESP | A | 2.2 | | 10 | 35 | 2.1 | 1.6 | 0.43-2.2 | B |
| | | 2.0 | | 3 | 49 | | | | |
| | B | 0.43 | | 3 | 48 | 0.53 | | | |
| | | 0.63 | | 3 | 41 | | | | |
| 3. Controlled by Wet ESP | B | 0.17 | | 38 | 56 | 0.17 | 0.17 | | B |
| | C | 0.03 | | 6 | 43 | 0.03 | | | |
| 4. Controlled by Scrubber | A | 0.7 | | 3 | 37 | 0.66 | 0.47 | 0.093-0.95 | B |
| | | 0.32 | | 3 | 50 | | | | |
| | | 0.95 | | 6 | 138 | | | | |
| | B | 0.093 | | 3 | 56 | 0.093 | | | |
| 5. Controlled by Cyclone | B | 1.0 | | 16 | 14 | 1.0 | 1.0 | | B |
| B. Sinter Discharge (breaker and hot screens) | | | lb/T sinter | | | | | | |
| 1. Uncontrolled | B | 6.8 | | 15 | 32 | 6.8 | 6.8 | | B |
| 2. Controlled by Baghouse | B | 0.1 | | 3 | 48 | 0.1 | 0.1 | | B |
| 3. Controlled by Orifice Scrubber | A | 0.59 | | 3 | 138 | 0.59 | 0.59 | | A |
| C. Windbox and Discharge | A | 0.3 | | 3 | 140 | 0.3 | 0.3 | | A |
| 1. Controlled by baghouse | | | | | | | | | |
| IV. BOFs | | | | | | | | | |
| A. Top Blown Furnace Melting and Refining | | | lb/T steel | | | | | | |
| 1. Uncontrolled | A | 24.2 | | 5 | 137 | 24.2 | 28.5 | | B |
| | B | 17.0 | | 5 | 58,59 | 17.0 | | | |
| 2. Controlled by Open Hood Vented to: | | | | | | | | | |
| a. ESP | A | 0.0614 | | 5 | 137 | 0.13 | 0.13 | 0.0614-0.21 | A |
| | | 0.105 | | 3 | 64 | | | | |
| | | 0.21 | | 3 | 65 | | | | |
| | C | 0.052 | | 3 | 66 | 0.052 | | | |
| b. Scrubber | B | 0.15 | | 7 | 58 | 0.09 | 0.09 | 0.033-0.15 | B |
| | | 0.033 | | 3 | 61 | | | | |
| | C | 0.09 | | 3 | 57 | 0.098 | | | |
| | | 0.106 | | 3 | 72 | | | | |

(continued)

TABLE 18. (continued)

| Source | Test series: Rating | Average EF ($EF_i$) | EF units | Number of runs | Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value: Average | Range | Rating |
|---|---|---|---|---|---|---|---|---|---|
| 3. Controlled by Closed Hood Vented to: | | | | | | | | | |
| a. Scrubber | A | 0.0028 | | 3 | 67 | 0.0068 | 0.0068 | 0.0028-0.0132 | A |
| | | 0.0044 | | 3 | 68 | | | | |
| | | 0.0132 | | 3 | 71 | | | | |
| B. O-BOF Melting and Refining | | | lb/T steel | | | | | | |
| 1. Controlled by Scrubber | A | 0.0556 | | 2 | 73 | 0.056 | 0.056 | | A |
| C. BOF Charging | | | lb/T hot metal | | | | | | |
| 1. At Source | A | 0.6 | | 6 | 134 | 0.6 | 0.6 | | A |
| 2. At Building Monitor | B | 0.142 | | 15 | 81 | 0.142 | 0.142 | | B |
| D. BOF Tapping | | | lb/T steel | | | | | | |
| 1. At Source | A | 0.92 | | 3 | 134 | 0.92 | 0.92 | | A |
| 2. At Building Monitor | B | 0.29 | | 15 | 80 | 0.29 | 0.29 | | B |
| E. Hot Metal Transfer | | | lb/T hot metal | | | | | | |
| 1. At Source | A | 0.19 | | 8 | 133 | 0.19 | 0.19 | | A |
| 2. At Building Monitor | B | 0.056 | | 8 | 82 | 0.056 | 0.056 | | B |
| F. BOF Monitor (all sources) | B | 0.5 | lb/T steel | 3 | 84 | 0.5 | 0.5 | | B |
| | C | 0.28 | | 1 | 83 | 0.23 | | | |
| | | 0.3 | | 3 | 85,143 | | | | |
| | | 0.147 | | 4 | 86,87 | | | | |
| V. EAFs | | | | | | | | | |
| A. Melting and Refining | | | lb/T steel | | | | | | |
| 1. Uncontrolled | | | | | | | | | |
| a. Carbon steel | C | 50 | | ?-assume 1 | 97 | 38 | 38 | 22-51 | C |
| | | 51 | | ?-assume 1 | 98 | | | | |
| | | 22 | | ?-assume 1 | 99 | | | | |
| | | 27.5 | | ?-assume 1 | 99 | | | | |
| B. Charging, Tapping, and Slagging | | | lb/T steel | | | | | | |
| 1. Uncontrolled Emissions Escaping Monitor | C | 1.2 | | ?-assume 1 | 99 | 1.2 | 1.4 | 1.2-1.7 | C |
| | | 1.7 | | ?-assume 1 | 100 | 1.7 | | | |

(continued)

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TABLE 18. (continued)

| Source | Rating | Test series: Average EF ($EF_1$) | Test series: EF units | Test series: Number of runs | Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value: Average | Calculated single EF value: Range | Calculated single EF value: Rating |
|---|---|---|---|---|---|---|---|---|---|
| C. Melting, Refining, Charging, Tapping, and Slagging | | | lb/T steel | | | | | | |
| 1. Uncontrolled | | | | | | | | | |
| a. Alloy steel | A | 11.3 | | 1 | 89 | 11.3 | 11.3 | | A |
| b. Carbon steel | C | 43.0 | | ?-assume 1 | 99 | 50 | 50 | | C |
| | | 58.0 | | ?-assume 1 | 101 | | | | |
| 2. Controlled by: | | | | | | | | | |
| a. Configuration 1 (building evacuation to baghouse for alloy steel) | A | 0.4 | | 9 | 89 | 0.3 | 0.3 | | A |
| b. Configuration 2 (DSE plus charging hood vented to common baghouse for carbon steel) | C | 0.043 | | 2 | 94 | 0.043 | 0.043 | | C |
| VI. OHF | | | | | | | | | |
| A. Melting and Refining | | | lb/T steel | | | | | | |
| 1. Uncontrolled | A | 21.1 | | 3 | 110 | 21.1 | 21.1 | | A |
| 2. Controlled by ESP | A | 0.28 | | 3 | 106 | 0.28 | 0.28 | | A |
| B. Roof Monitor Emissions | C | 0.168 | | 28 | 109 | 0.168 | 0.168 | | C |
| VII. Teeming | | | lb/T steel | | | | | | |
| A. Leaded Steel | | | | | | | | | |
| 1. Uncontrolled (as measured at the source) | A | 0.81 | | 1 | 111 | 0.81 | 0.81 | | A |
| 2. Controlled by Side-draft Hood Vented to Baghouse | A | 0.0038 | | 1 | 111 | 0.0038 | 0.0038 | | A |
| B. Unleaded Steel | | | | | | | | | |
| 1. Uncontrolled (as measured at the source) | A | 0.07 | | 6 | 111 | 0.07 | 0.07 | | A |
| 2. Controlled by Side-draft Hood Vented to Baghouse | A | 0.0016 | | 6 | 111 | 0.0016 | 0.0016 | | A |
| VIII. Machine Scarfing | | | | | | | | | |
| A. Uncontrolled | B | 0.1 | lb/T metal through scarfer | 1 | 111 | 0.1 | 0.1 | | B |
| B. Controlled by ESP | A | 0.08 | lb/T metal through scarfer | 1 | 111 | 0.023 | 0.023 | 0.001-0.08 | A |
| | | 0.001 | | 1 | 112 | | | | |
| | | 0.008 | | 1 | 112 | | | | |
| | | 0.032 | | 1 | 112 | | | | |
| | | 0.015 | | 1 | 112 | | | | |
| | | 0.003 | | 1 | 112 | | | | |

(continued)

## TABLE 18. (concluded)

| Source | Rating | Average EF ($EF_A$) | Test series EF units | Number of runs | Bibliography reference | Average EF for rating category (EF average) | Calculated single EF value Average | Range | Rating |
|---|---|---|---|---|---|---|---|---|---|
| IX. Miscellaneous Combustion Sources | | | | | | | | | |
| A. Boilers Burning the Following: | | | lb/$10^6$ Btu | | | | | | |
| 1. Blast Furnace Gas | D | 0.035 | | - | 120-122 | 0.035 | 0.035 | | D |
| 2. Coke Oven Gas | D | 0.012 | | - | 120-122 | 0.012 | 0.012 | | D |
| 3. No. 6 Fuel Oil | A | 0.09 | | - | AP-42 | 0.09 | 0.09 | | A |
| 4. Bituminous Coal | A | 6.4 | | - | AP-42 | 6.4 | 6.4 | | A |
| 5. Natural Gas | A | 0.01 | | - | AP-42 | 0.01 | 0.01 | | A |
| B. Soaking Pits Burning the Following: | | | lb/$10^6$ Btu | | | | | | |
| 1. Coke Oven Gas | D | 0.012 | | - | 120-122 | 0.012 | 0.012 | | D |
| 2. No. 6 Fuel Oil | D | 0.09 | | - | AP-42 | 0.09 | 0.09 | | D |
| 3. Natural Gas | D | 0.01 | | - | AP-42 | 0.01 | 0.01 | | D |
| C. Slab Reheat Furnaces Burning the Following: | | | lb/$10^6$ Btu | | | | | | |
| 1. Coke Oven Gas | D | 0.012 | | - | 120-122 | 0.012 | 0.012 | | D |
| 2. No. 6 Fuel Oil | D | 0.09 | | - | AP-42 | 0.09 | 0.09 | | D |
| 3. Natural Gas | D | 0.01 | | - | AP-42 | 0.01 | 0.01 | | D |

a/ Even though the tests were performed in an acceptable manner and all data were reported (A-rating), there are independent variables which effect the EF measurement and caused the wide range of results (see p. 12).

The value 3 was selected as the cutoff point for weighting averages of test series averages. This value arises from the unwritten rule generally followed by the U.S. EPA that 3 tests are sufficient to quantify emissions from a source. This is evidenced by the multiplicity of sets of three tests used in the published background documents for BOF[65-68, 71-72] and EAF[89] standards.

The process for identifying the test series averages that were excluded from Table 18 was as follows:

1. Test series averages reported in units incompatible with the selected reporting units shown in the Table 18 column entitled "EF Units" were excluded. For example, EFs for sintering operations reported in pounds per ton input could not be converted to pounds per ton sinter for two reasons. First, input can be defined in three ways--raw material from bins, raw material from bins and recycle fines, and finally, raw material from bins, recycle fines, and hearth layer. The definition utilized was not made clear in many of the reports. Second, depending on plant operations, the mass ratio between input and output product may not be the same from plant to plant.

2. Test series averages representing front and back half particulate as measured by EPA Method 5 were excluded. Test series which were reported unclearly as to whether they represented front and back half or just front half particulate were also excluded.

3. Test series for controlled tests for which the control device was not specified were excluded.

4. Test series that were unclearly reported as to what process source they represented were excluded.

5. Test series that were reported unclearly as to whether they were controlled or uncontrolled were excluded.

The rules for calculating the representative EF for a source were:

1. If any source category has four or more A-rated test series, then the representative EF value shall be equal to the average of these A-rated test series as determined by Equation 1.

2. If any source category has less than four A-rated test series but more than zero, then the representative EF value shall be a weighted average of the A- and B-rated averages with the A-rated EF average receiving twice the weight that the B-rated EF average does.

3. If there are no A-rated values, then the representative EF value shall be equal to the average of the B-rated test series averages as determined by Equation 1.

If there are no A- and B-rated values, then the representative EF value shall be equal to the average of C- and D-rated values.

The philosophy behind the above rules is as follows. If there is a significant number of A-rated test series, that is, tests performed by a sound methodology and reported in enough detail to adequately validate the test series, then the single value should be set equal to the average of the A-rated values alone. If there is not enough A-rated test series to cover a significant number of plants (estimated as four), then the B-rated test series should also be included in the averaging process so that the single EF value approaches a true industry-wide average. But, in order to counterbalance the fact that B-rated test series may not have been performed properly, the A-rated average should be weighted as more important than (twice as heavily as) the B-rated average. If there are no A-rated test series, then the single value should be set equal to the average of the B-rated test series. No C- or D-rated test series should be included with A- or B-rated tests in determining the single EF, since they were performed by either an unacceptable or unknown methodology or are based on estimates which cannot be corroborated. If there are no A- or B-rated test series, then the single EF value should be set equal to the average of the C- and D-rated test series. This provides at least an order of magnitude value for the source, but should by no means be expected to provide any more precision. These C- and D-rated test series are only used as a last resort since no other data are available.

## 4.2 OPEN DUST SOURCES

The single EFs that should be used to represent open dust sources at existing plants are shown in Table 13. These factors are in the form of predictive equations and, consequently, their use necessitates that the independent variables be quantified. For cases where estimates must be made for plant expansions or new plants, the equations in Table 13 can also be used, but the independent variables will necessarily have to be estimated. The average values presented in Tables 15-17 could be used for these estimates.

## SECTION 5.0

## SUMMARY

The purpose of this report was to develop a representative particulate EF or predictive equation for each significant source in the iron and steel industry. To accomplish this, results of emission tests performed by industry, EPA contractors, local, state, and regional environmental regulatory bodies were compiled in Section 3.0 and each EF rated as to its reliability.

For process stack and fugitive emissions, weighted averages of the most reliable tests were then calculated in Section 4.0 to develop representative particulate EF values as shown in Table 18. Unfortunately, much of the compiled data were not useful in determining the final representative EF value for reasons of unreliability, reporting of the production rate in incompatible units, inclusion of condensable emissions, unspecified control devices, and lack of clarity concerning which sources were actually sampled.

For open dust sources, predictive equations as shown in Table 13 were selected as the most accurate method to predict emissions from existing and proposed plants. The large difference in EF values for the same source due to varying raw or intermediate material characteristics or climatic variation with geographic location can then be predicted.

In conclusion, it is important to repeat the caution in Section 1.0 that the values in Tables 13 and 18 are average EFs obtained from a wide range of data of varying degrees of accuracy. The reader must be cautioned not to use these emission factors indiscriminately. That is, the factors generally may not yield precise emission factors for an individual installation. Only on-site source tests can provide data sufficiently accurate and precise to determine actual emissions for that source. Emission factors are most appropriate when used in diffusion models for the estimation of the impact of proposed new sources upon the ambient air quality and for community or nationwide air pollution emission estimates.

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# APPENDIX

## TYPICAL CONVERSION FACTORS FOR MATERIAL FLOW CALCULATIONS

TABLE A-1. TYPICAL CONVERSION FACTORS UTILIZED FOR ENGINEERING ESTIMATES OF QUANTITIES OF MATERIAL HANDLED

| Process | Conversion factor | Reference |
|---|---|---|
| Coke manufacture | 1.0 unit coal / 0.69 unit coke | - |
| Iron production | 0.55 unit coke / 1.0 unit iron | 1 |
| | 1.55 units of iron bearing material / 1.0 unit iron | 1 |
| | 0.5 unit sinter / 1.0 unit iron | Average of 5 years of AISI data |
| | 1.0 unit iron ore / 1.0 unit iron | Calculated by difference |
| | 0.2 unit limestone / 1.0 unit iron | 1 |
| | 0.2 unit slag / 1.0 unit iron | 1 |
| | or | |
| | 0.3-0.4 unit slag / 1.0 unit iron | 2 |
| | or | |
| | 0.2-0.35 unit slag / 1.0 unit iron | 3 |
| BOF steel production | 0.7 unit hot metal / 1.0 unit BOF steel | 4 |
| | 0.3 unit scrap / 1.0 unit BOF steel | |
| OHF steel production | 0.45-0.55 unit hot metal / 1.0 unit OHF steel | |
| | 0.45-0.55 unit scrap / 1.0 unit OHF steel | |

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